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# IRON AND STEEL ENGINEER

VOL. XIII DECEMBER • 1936 NO. XII

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# ASSOCIATION ACTIVITIES

## BIRMINGHAM DISTRICT SECTION

December 17, 1936

Joint Meeting of all Engineering Societies at the Phillips High School with sound pictures of San Francisco-Oakland Bridge. Introductory remarks will be made by C. S. Goodrich, Chief Engineer, American Bridge Company.

## CHICAGO DISTRICT SECTION

January 5, 1937

Phil Smidt's Restaurant
1170 Indianapolis Blvd.
Roby, Indiana

Dinner 6:15 P.M.
Meeting 7:45 P.M.

**"Modern Practices in Steam Generating Plants"** by A. G. Darling, General Electric Co., Schenectady, N. Y.

## CLEVELAND DISTRICT SECTION

January 15, 1937

Cleveland Engineering Society Room,
Cleveland, Ohio

Meeting 8:00 P.M.

**"Cold Roll Forming and Bending of Sheet Metal,"** by Carl M. Yoder, President, Yoder Manufacturing Company, Cleveland, Ohio.

## PHILADELPHIA DISTRICT SECTION

January 9, 1937

Engineers Club of Philadelphia,
1317 Spruce Street,

Dinner 6:00 P.M.
Meeting 7:00 P.M.

**"Modern Developments in Steam Power Generation,"** by A. G. Christie, Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Md.

## PITTSBURGH DISTRICT SECTION

December 19, 1936

Cardinal Room,
William Penn Hotel,

Dinner 6:30 P.M.
Meeting 8:00 P.M.

**"Water Lubrication"** by Harry R. Gilchrist, Lubrication Engineer, Youngstown District, Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

## NATIONAL MEETINGS

February 25, 1937
Youngstown, Ohio

**Technical Sessions and Inspection Trip** to Youngstown Sheet & Tube Company, Campbell Works, Youngstown, Ohio.

## SPRING ENGINEERING CONFERENCE

April 28, 29, 1937
**Technical Sessions,** Statler Hotel, Buffalo, New York
April 29
**Inspection Trip to Strip Mill Installations,** Bethlehem Steel Company, Lackawanna, New York.

## ANNUAL CONVENTION—IRON AND STEEL EXPOSITION

Stevens Hotel, Chicago, Illinois

September 28, 29, 30 and October 1, 1937

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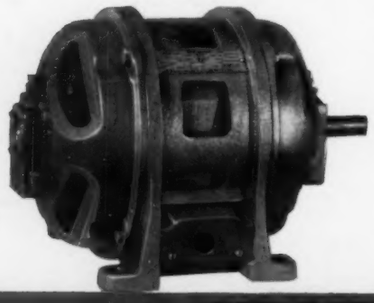

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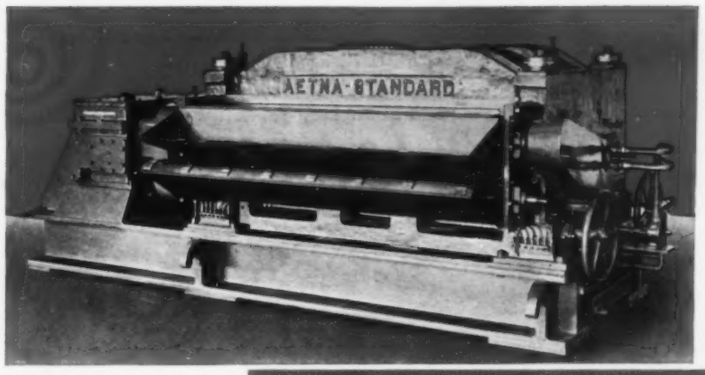


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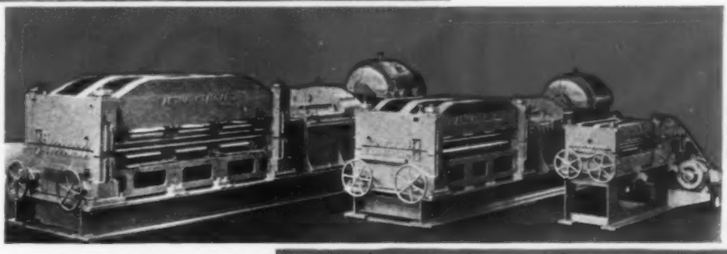

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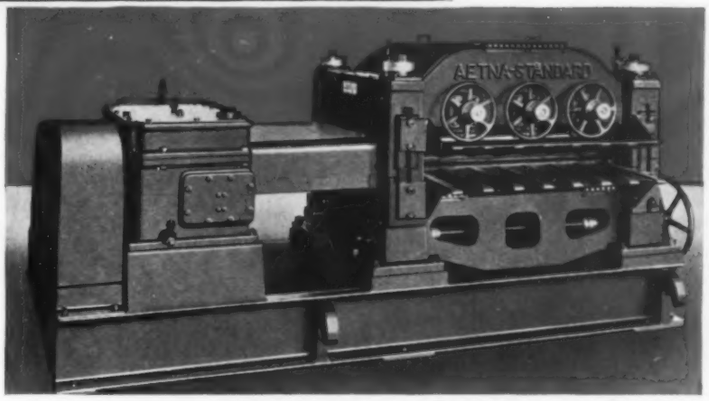


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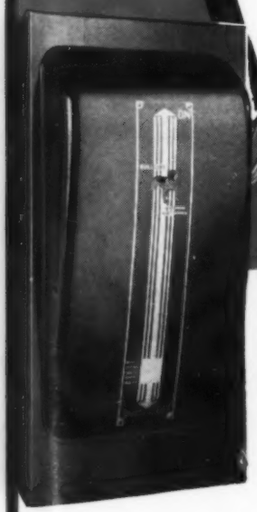

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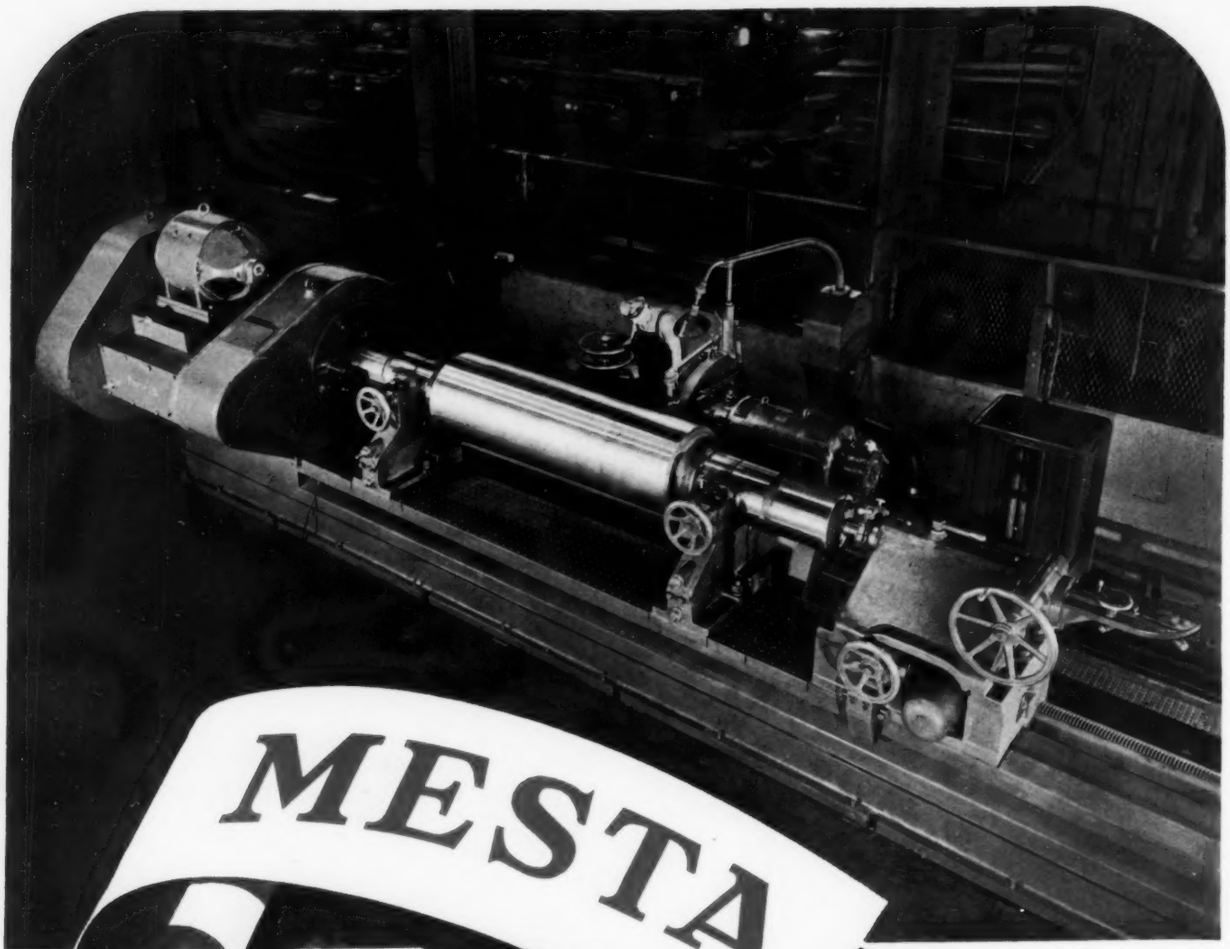

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# *Sheet and Strip Steel*

## FOR DEEP DRAWING PURPOSES

**Presented before the Annual Convention of the A. I. & S. E., Detroit, Michigan, Sept. 22-25, 1936**

By JOSEPH WINLOCK, Chief Metallurgist
Edward G. Budd Manufacturing Co.
PHILADELPHIA, PA.

▲ I KNOW of no subject which more clearly illustrates the general observation that the "art precedes the science" than the development of the deep drawing process. This is not only because the subject of plastic flow in metals is an extremely difficult one, but also because the unsymmetrical and complicated shape and contour of most stampings do not permit an analysis of the distribution and magnitude of the imposed stresses. A discussion of steel for deep drawing can be undertaken only with a full realization that the manner in which the draw is accomplished is, within limits, of equal importance to the success of the operation as the physical properties of the steel itself. The subject cannot, therefore, be approached from any one point of view. Theories,—metallurgical or otherwise,—are of little value unless a knowledge of the practice gives some promise of their successful application. Such a situation very clearly demands the closest kind of cooperation between the metallurgist and the men in the steel mill and in the press shop. If this cooperation is lacking, misunderstandings occur and erroneous conclusions are often drawn which severely handicap our efforts to progress.

The steel most widely used for deep drawing purposes is a plain carbon basic open hearth steel containing carbon under 0.10%; manganese under some 0.35% with low phosphorous and sulphur. This maximum carbon content has been specified because experience has shown that an increase in carbon above this figure leads to a too marked decrease in the ductility of the steel. There are, of course, exceptions to this rule such as steel for light draws or for a series of draws with intermediate annealing processes. The present tendency is to use steel of the "rimming" type almost entirely. If this process is correctly carried out, an ingot is produced which has a thick skin of dense metal surrounding a core of spongy metal which contains most of the impurities. The blow holes in the center of the ingot readily weld up in the subsequent rolling processes and the thick skin of dense metal results in better surface qualities.

It would be beyond the scope of this paper to describe in detail the different mill operations from the open hearth to the finished product which are used in the manufacture of steel for deep drawing. It is necessary only to point out that there are two general methods: (1) the sheet method and, (2) the strip method. The essential difference between the two methods is that in the strip method a large part and sometimes all of the rolling is done in one direction, whereas in the sheet method the ingot is first rolled to a sheet bar and then cross rolled to the approximate finished gauge. The particular method used depends, of course, upon the equipment available in each steel mill. Most of the large steel companies have, in recent years, adopted the strip method and a large part of the reduction to light gauges is performed cold. Whatever method is used, however, the general outline of procedure consists in a series of hot rollings, cold rol-

JOSEPH WINLOCK

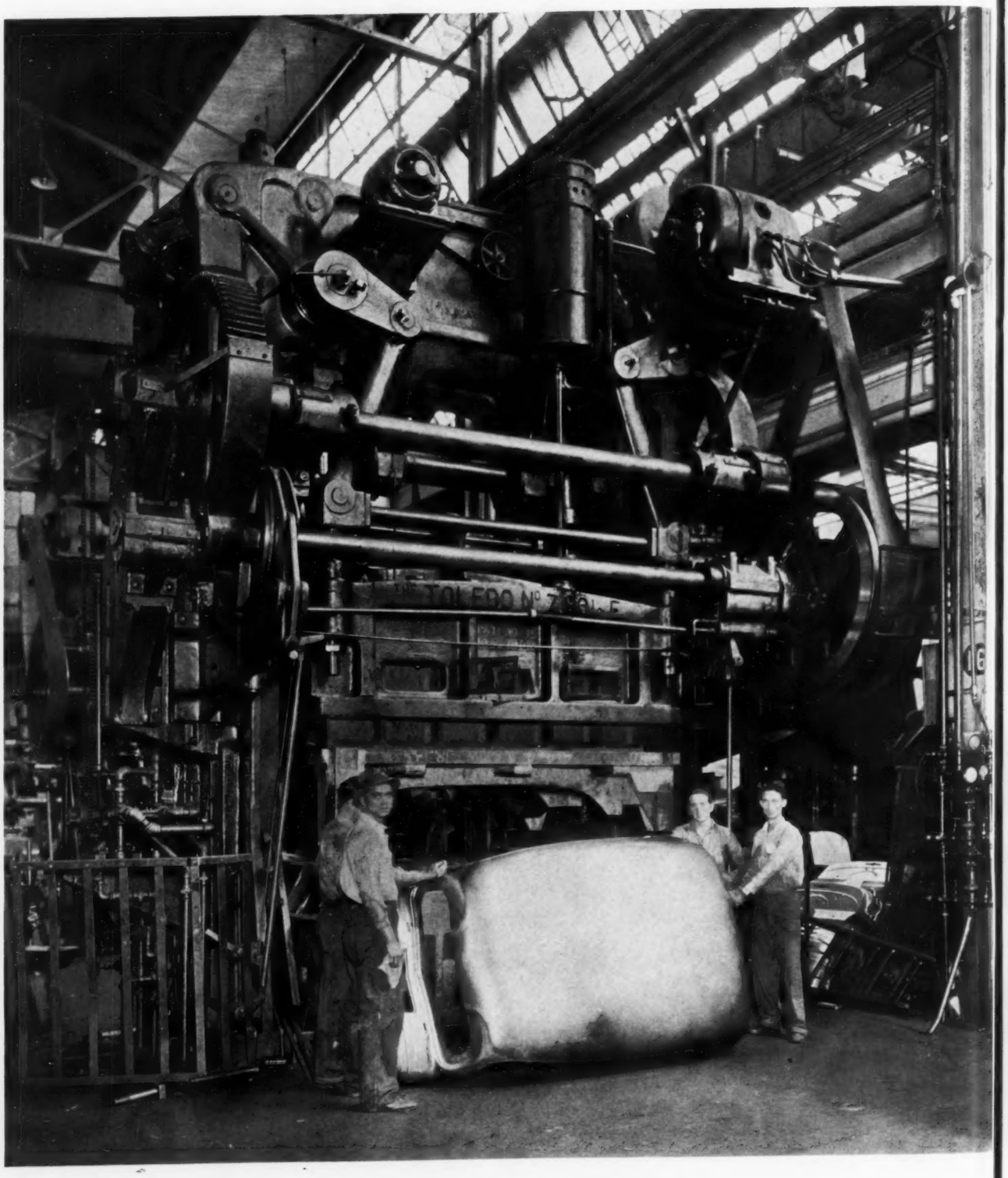


Figure 1—Large press used for deep drawing.

lings, annealing operations and pickling operations. The number and sequence of these operations depend also upon the deep drawing qualities and the surface qualities needed or desired in the finished product.

## HOT ROLLING

The first important operation after the making of the steel and the casting of the ingot is hot rolling. As this rolling commences on the hot mills, the crystalline grains of the steel are drawn out in the direction of rolling. If the temperature at which this rolling is carried out is above some 1100 deg. F. "spontaneous" annealing may take place. By "spontaneous" annealing is meant that enough residual heat remains in the steel after rolling to prevent the occurrence of distorted grains in the metal when it has reached room temperature. Hot rolling produces a refinement of the grain structure of the steel because grain growth requires slow and undisturbed cooling. When steel is hot rolled to the lighter gauges, the finishing temperatures on the hot mill are usually so far below the temperature at which spontaneous annealing takes place that a considerable amount of the deformation is actually cold work. This accounts for the fact that steel which has been rolled on the hot mill is often susceptible to grain size changes on subsequent annealing or heating for further rolling. Low finishing temperatures are often necessary, however, in order to obtain good surface qualities. Figures 2, 3 and 4 show some of the different structures which may be obtained in hot rolled steel.

The amount of cold work in steel rolled on the hot mill may often be so great that "exaggerated" grain growth may occur on annealing and may persist through to the finished sheet. This is unlikely to occur in strip steel because of the higher rolling speeds and because the subsequent amount of reduction produced by cold rolling is usually so great that all vestiges of large grain growth disappear on annealing. Hot rolled steel of the heavier gauges (14 and under) usually show very little of the effects of cold work because of the slower rate of cooling.

Long heating at high temperatures preparatory to hot rolling is injurious, because of the pitting of the surfaces of the metal by scale. Decarbonization of the metal will often take place in heating unless a reducing or neutral atmosphere exists in the furnace. Decarbonization, obviously, detracts from the uniformity of the finished product.

## COLD WORK

Sheet steel is cold rolled primarily to obtain good surface qualities, uniform gauge, and flatness, i. e., freedom from buckles and waves. The reductions in thickness produced by cold rolling are seldom more than 3 per cent. Strip steel is cold rolled for the same reasons, with the additional purpose of rolling to the lighter gauges. In the case of strip steel, the reductions effected by cold rolling are usually 20 per cent or more and often are as high as 60 per cent. A final light pass (sometimes called a "temper" pass or a "pinch" pass) is often given the steel in order to reduce the tendency for "stretcher strains" to occur during the deep draw-

Figures 2, 3 and 4—Photomicrographs of hot rolled steel magnified 75 diameters.

ing operation. This tempering pass increases, also, the "stiffness." The term "stiffness" as applied to metals is often misunderstood and therefore often misused. Stiffness is sometimes thought of as being synonymous with rigidity and the incorrect conception is, therefore, obtained that cold rolling increases the resistance to deformation. But this is not true. All steels whether they have been cold rolled or not, or whether they contain alloys or not, have the same resistance to deformation. A steel which has been severely cold rolled, for example, when compared with one which has not been cold rolled will *not* resist a greater load (as in bending or in tension) before elastic deformation takes place, but the severely cold rolled steel having a higher elastic limit can be deformed a greater amount and withstand a greater load before permanent deformation takes place. In other words, the modulus of elasticity (the ratio of stress to strain) for steel is 30,000,000 lbs. per sq. in. and remains practically unchanged for any analysis or treatment. In passing, it should be pointed out that this value is greater by far than for any other metal in commercial use.

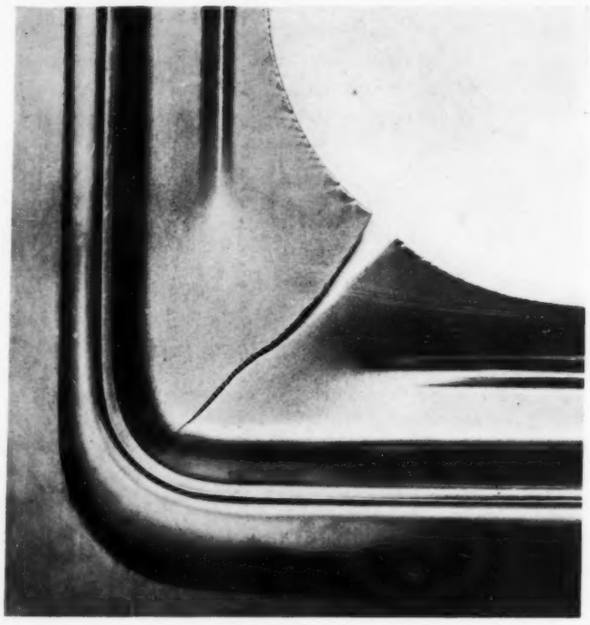


Figure 6—Tears resulting from stretching a blanked edge, magnified 75 diameters.

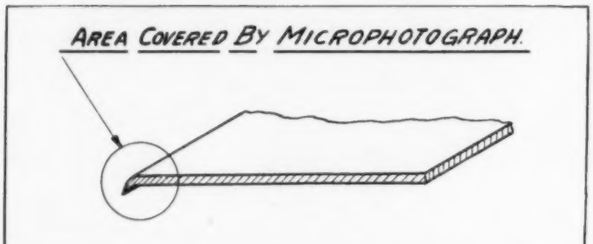



Figure 5—Photomicrograph of a sheared edge of sheet steel showing elongated grains caused by cold work.

Mechanical deformation of iron and steel at low temperatures greatly affects the physical properties of metals, the elastic limit, tensile strength, and hardness being increased, while the ductility as represented both by the percentage elongation and reduction of area is decreased. The density is slightly decreased. Evidences of reductions by cold rolling even as large as 15 per cent cannot be detected under the microscopé, but the physical properties are, nevertheless, deeply affected by reductions even as low as 0.5 per cent.

The percentage elongation in tensile specimens taken in a direction parallel to the direction of rolling is generally slightly higher and the tensile strength and yield point generally slightly lower than in tensile specimens taken in a direction transverse to the direction of rolling. Cold rolling tends to accentuate this difference in that the rate of change to a lower ductility, for a given amount of reduction, is greater in the transverse direction than in the longitudinal direction. As a result of this, blanks for stampings are laid out wherever possible, so that the maximum amount of draw will take place in a direction parallel to the direction of rolling. And, in particular, bending of the metal flat on itself ("dutch bending") in a line parallel to the direction of rolling is avoided as much as possible.

In deep drawing, the elongation or stretching of a blanked or sheared edge is undesirable. This is because the blanking or shearing operation, as a result of the attendant cold work, causes a decrease in the ductility at the edge of the metal. Incipient tears may also be produced. The presence of these small tears causes, in drawing, concentrations of the imposed stress just as a small cut facilitates the tearing of a piece of heavy cloth. Fracture of the metal occurs, then, by a tearing action. Fig. 5 shows the microstructure of a sheared edge of sheet steel with elongated grains caused by the

cold work, and Fig. 6 shows the tears which often occur in a stamping as a result of the conditions just mentioned. The use of blanking dies which are not sharp or properly aligned obviously accentuates these conditions. Fractures due to these causes may often be prevented either by filing or grinding away the damaged edge, or by annealing it.

If, after the yield point has been passed, the load producing the deformation is removed, it will be found that the total permanent deformation is smaller, i. e., a slight amount of elasticity remains in the steel. This is shown in the stress-strain curves of the two steels in Fig. 7. As the stress after a given amount of deformation is removed, the relation of stress to strain returns along the line C D for steel No. 1 and the line B A for steel No. 2, instead of along the perpendicular lines C E and B C E. The length of the lines D E and A D E is then, a measure of the residual elasticity in the two steels respectively. In the deep drawing process, this phenomenon is known as "spring back". Upon further examination of Fig. 7, it will be seen that the greater the stress, the larger will be the amount of "spring back". From this it follows that the higher the tensile properties of the steel, the greater will be the amount of "spring back". Allowance must be made for this property of steel by so designing the dies for deep drawing operations that the metal will be deformed an

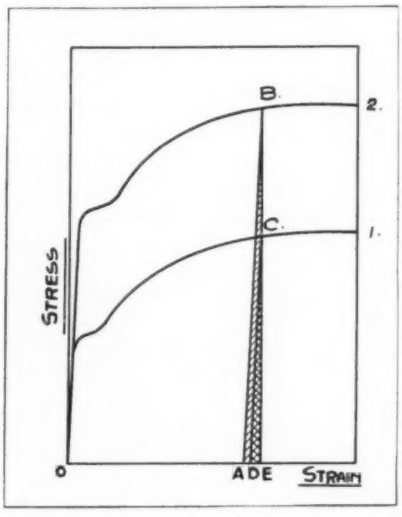



Figure 7—Stress-strain curve illustrating "spring back."

amount greater than that desired in the finished stamping. It can be readily seen that if this were not done, the stamping would not be of the correct shape after removing it from the die. No general rules can be formulated regarding the proper allowances to be made for spring back because the amount varies widely for each design of stamping.

An approximate measure of the "toughness" of the steel may be expressed by the area under the stress-strain curve and the higher the yield point and the tensile strength the larger this area becomes. Experience has shown that the greater the toughness, the greater is the tendency for buckles to occur during the deep drawing operation and, because of the greater loads necessary for deep drawing, greater wear on the dies will result.

Figure 8—Photograph of portion of stamping showing coarseness due to large grain size.

## ANNEALING

The "box-annealing" process and the "normalizing" process are the two principal methods used for annealing sheet and strip steel. As the name implies, the former is carried out in boxes inserted in furnaces. The temperatures employed in box-annealing are below the $AC_3$ point of the steel (usually between 1150 and 1400 degrees F.). The normalizing process is carried out in continuous type furnaces above the $AC_3$ point (about 1700 deg. F.). In box-annealing the metal is annealed in piles, whereas in the normalizing process each piece is annealed individually or in pairs. The maximum temperature obtainable in box-annealing is governed by the quality of the surface and the weight of the charge. In general, the better the surface qualities, the lower is the temperature which can be reached because of the greater tendency toward welding ("sticking"). This tendency is increased as the weight of the charge increases. When annealed in coils placed in upright positions in boxes, this difficulty does not exist to the same extent, with the result that higher temperatures may be used.

The mechanism of the recrystallization which takes place at low temperatures after cold work (as in box annealing) is, of course, somewhat different from that which takes place as the steel passes through the $AC_3$ point. In the former, the structure of the metal consists of an aggregate of alpha iron (ferrite) and pearlite or spheroidized cementite. In this case, recrystallization (if it really may be called this, since there is no change in atomic arrangement) takes place by a growth of the small grain fragments produced by the cold work. In high temperature annealing, the condition is reached in which the structure of the metal consists of a more or less homogeneous solid solution of carbon in gamma iron (austenite). In both cases, the size of the resultant grains is governed by the usual laws of grain growth in which time, temperature, temperature

gradients, grain size, grain size contrast, rate of heating and cooling, etc., take such important parts. In low temperature annealing, there is the additional influence of strain and strain gradients. It should also be emphasized, then, that the effect of the *amount* of reduction by cold rolling is greater in low temperature annealing than in high temperature annealing. When the reductions are small, there is usually no marked change in the size of the grains as a result of a low temperature anneal. When the reductions are larger, however, we may obtain, and usually do, a decrease in the size of the grains as a result of the large reduction in cold rolling and the low temperature anneal. In effect, an actual refinement of the grains takes place.

There are two principal conditions to be avoided in annealing steel for deep drawing purposes: The first is the production of too large a grain size, and the second is the production of too small a grain size. A sheet metal having a large grain size will exhibit, after deep drawing, a coarse granulated surface, known in the shop as "orange peel". This requires filing and polishing in order to obtain a smooth surface on the finished stamping. The degree of coarseness is directly proportional to the grain size. Fig. 8 shows a portion of the surface of a stamping made from a steel in which the grain size was very large.

A steel having a large grain size is subject to the phenomenon known as "Stead's brittleness" more often than a steel of small or medium grain size. This is a peculiar type of brittleness which sometimes occurs after cold working and annealing. It is due to the crystalline grains assuming the same or nearly the same orientation. Steel in this condition is very susceptible to fracture by dynamic stresses. Fractures sometimes occur by simply dropping the metal on the floor. Fractures resulting from this type of brittleness usually occur when the major stress is at 45 degrees to the direction of rolling. Thus, a steel may draw perfectly in a preliminary operation and then exhibit extreme brittleness in a subsequent operation in which the application of the stress has been from a slightly different direction. Straightening or flattening stampings by means of trip hammers often causes fracture of steel in this condition. Figure 9 is a photograph of a portion of a large stamping which shows this type of brittleness.

Sometimes the phenomenon known as "exaggerated" or "critical" grain growth occurs. This was first investigated by Sauveur and Chappell who found that a low annealing temperature, 1200 degrees F. (650 degrees C.), caused the development of a course crystalline structure in low carbon steel which had been subjected to a certain amount of cold plastic deformation. Where the strain was more or less than this amount, heating to this temperature did not produce a coarse grain. It occurs only when the carbon content of the steel is below some 0.15 per cent.

The condition which most readily results in the occurrence of exaggerated grain growth is a reduction in cold rolling of about 5-15 per cent followed by heating at various temperatures from 1150 degrees F. (620 degrees C.) to the $Ac_3$ point of the steel. Exaggerated grain growth may sometimes occur in steel, which has been box-annealed at these temperatures, as a result of "critically" straining the steel by finishing at too

Figure 9—Photograph of a portion of a large stamping showing profile of fracture peculiar to steel's brittleness.

low a temperature on the hot mill, by an unusual amount of cold rolling, or by the combined effect of a small amount of cold work on the hot mill followed by the usual amount of cold rolling. Large grains produced in sheet steel or strip steel, whether or not they have been produced in this manner, can be removed by either heating above the $Ac_3$ point of the steel or by severe cold rolling followed by annealing at lower temperatures. Figure 10 shows the entire cross section of a sheet of steel in which exaggerated grain growth has occurred. It will be seen that the grain size is so large that there is approximately only one grain in the entire section.

Sheet metal having too small a grain size exhibits in too great a degree the property referred to as "toughness". Steel having too small a grain size is more susceptible to "stretcher strains" and often shows marked stubborness when attempts are made to prevent these from occurring.

Our experience has shown in the matter of grain size that a steel having some 84 grains per sq. in. at a magnification of 100 diameter (corresponding to a grain diameter of $\frac{1}{8}$ of an inch at the same magnification) does not "draw coarse" nor does it present too great a degree of "toughness". Neither does it present too great a stubborness in preventing the occurrence of stretcher strains during the deep drawing operation.

Of the different methods of testing and correlation of the different properties obtained with the behavior of the steel on the presses, our experience has been that the percentage elongation as obtained in the ordinary tensile test gives the most reliable indication of the

deep drawing properties of sheet and strip steel, and, further, that this property is of greatest value when obtained from specimens taken in directions both parallel and transverse to the direction of rolling. For this test, the standard specimen for sheet metals is used which has a 2 inch gauge length on a parallel section 0.5 inches wide. For the most difficult stampings, it has been found that a percentage elongation of some 38.0 to 40.0 per cent is necessary.

## STRETCHER STRAINS

One of the greatest difficulties encountered in the forming of sheet and strip steel by the deep drawing process is the occurrence of "stretcher strains" on the surfaces of the metal. Stretcher strains, or more appropriately "worms" are the shop names for the phenomenon known as the "lines of Luder" after Luder of Magdeburg who first described them in 1860. These lines appear on the surfaces of the steel after drawing as irregular lines of depressions or elevations which destroy the evenness of the surfaces of the metal. If the stresses producing the deformation are primarily tensile, the lines appear as depressions in the surface; but if the stresses are primarily compressive, irregular lines of elevations occur. They tend to occur in those stampings or those parts of stampings in which the elongation in forming is between 1.5 and 10.0 per cent. Sometimes these markings are so extensive that it is necessary to grind and polish the entire surface of the stamping, (see Fig. 11). Even this is not always accomplished satisfactorily because the heat produced by these operations tends to cause a severe distortion of the stamping.

As is well known, when a stress is applied to steel, the resulting deformation is either mainly elastic or mainly plastic according to the amount of the imposed

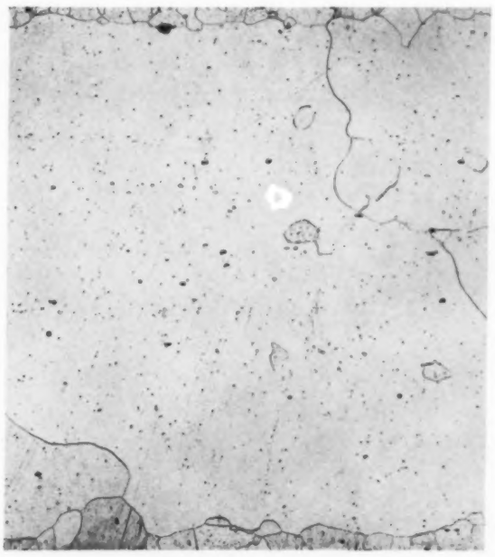


Figure 10—Cross section of a specimen of sheet steel showing exaggerated grain growth magnified 75 diameters.

Figure 11—Photograph of portion of stamping showing stretcher strains.

stress. Elastic deformation is produced when the intensity of the stress is of such an amount that no permanent deformation will remain when the load is removed. In elastic deformation, the stress is proportional to the strain. This is shown in the load-deformation diagram in Fig. 12. When, however, the stress is of such a magnitude as to produce permanent deformation, the deformation is mainly of a plastic nature. In iron and low carbon steel permanent deformation does not take place in all of the grains simultaneously, but occurs suddenly at different points throughout the stressed areas. This sudden transition from the elastic to the plastic state in iron and low carbon steel and the accompanying non-uniform and uneven plastic flow are most unusual and extraordinary phenomena. This peculiar property does not appear to be manifested to any marked extent in any other of the other metals in general use such as copper, brass, aluminum, etc.

The permanent deformation of iron and steel takes place, then, by an alternate slipping and work-strengthening of the different grains or groups of grains. It is obviously fortunate that work-strengthening does take place in metals because if this did not occur, the metal could not be formed by the deep drawing process. Molasses candy, for example, could not be drawn because no work-strengthening would take place at the point at which the cross-sectional area is first reduced. Fracture would occur almost immediately.

It is the differences in thickness produced by the uneven flow of the steel occurring at the yield point of the steel (see Fig. 12) which give rise to the surface markings known as stretcher strains. As deformation proceeds, this local slipping and work-strengthening

continues, and the extent and number of the depressions in the surfaces of the metal increase until the condition is reached where the entire surface has been so affected and the differences in cross sectional area become relatively minute. In effect this is a return to the original even surface. When this occurs, the load-deformation curve commences to rise again as a relatively smooth curve.

It has long been known that if enough permanent deformation or cold work is imposed on the steel before the deep drawing operation to cause all or most of the grains to slip partially, stretcher strains will not occur during the subsequent deep drawing operation. In Fig. 13 may be seen the load-deformation curve of a steel which has been previously slightly cold worked. The curve is now smooth from origin to fracture. Sheet and strip steel may be cold worked to produce this condition either by cold rolling or by roller leveling on machines designed to produce particularly drastic bending (see Figs. 14 and 15). Roller leveling is, in my opinion, the better of the two because (1) the amount of cold work done on the steel is less than that done by cold rolling, with the result that a higher ductility may be maintained in the steel and (2) in order to prevent "aging" from taking place, the cold working should be done *immediately before* the forming operation. This can be done by roller leveling but often cannot be done by cold rolling.

Steel in the "overstrained" condition just described is, however, in an unstable condition, and if the metal is permitted to rest or "age", it will recover its elasticity. It has been found that elastic recovery at the temperature of boiling water is as complete after a few minutes as in two weeks at room temperature. It is impeded or entirely prevented at lower temperatures, i. e., around 32 degrees F. On recovery, the steel will have a new yield point higher than that of the original material and will be slightly harder and less ductile. Our experience has been that for consistent results, the steel should be roller leveled within the twenty-four hour period preceding the deep drawing operation.

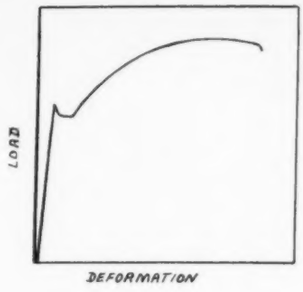



Figure 12—Load-deformation curve of low-carbon steel in annealed condition.

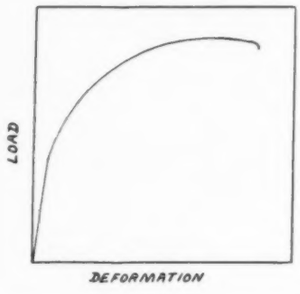
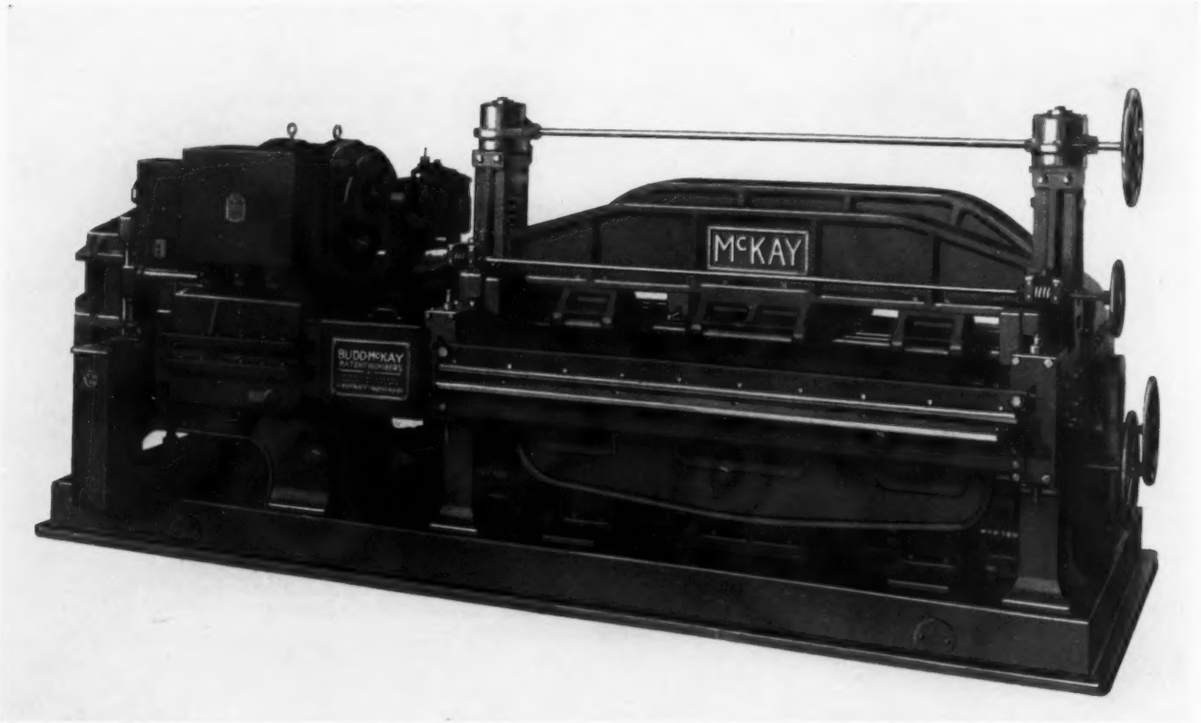



Figure 13—Load-deformation curve of low-carbon steel after cold working.

Figure 14—Roller leveler especially designed to remove stretcher strains.



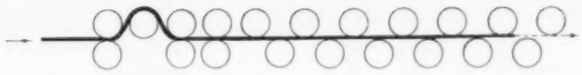


Figure 15—Sketch showing course of sheet through special roller leveler.

Cold rolling is a more drastic form of cold work and consequently longer intervals of time may elapse before the metal will recover from the effects of the "overstrain" thus produced.

There is another phase of the phenomenon which is of interest. If the steel shows a tendency to "kink" or to "break" in the roller leveling operation, this may be prevented sometimes by (1) using a steel of a larger grain size or (2) by gradually increasing the amount of bending in roller leveling. "Kinks" are simply localized stretcher strains and should not be allowed to occur because the drawing operation may not always be of such an amount as to result in their removal. Furthermore, if any aging is permitted to take place in the steel after kinking and before deep drawing, the steel may even be deformed until fracture occurs without removing the effects of the previous local deformation. In this case, markings appear as vein-like elevations on the surfaces of the metal. The persistent greater resistance to plastic flow shown by these regions has, of course, been induced by the greater amount of aging which occurred as a result of the cold work attending the formation of the original local deformation.

# DISCUSSION

PRESENTED BY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J. WINLOCK, Chief Metallurgist, Edward G. Budd Manufacturing Co., Philadelphia, Pa.


*K. L. Kerschbaum:* The importance of proper drawing practice cannot be over-emphasized as the die and drawing practice can either make or break the job, and Mr. Winlock is to be commended for pointing this fact out again in his review of the deep drawing process.

As this paper points out, the present methods of making sheets are: 1st, to hot roll on the hand mills, process by normalizing or other anneals; or 2nd, to hot roll into strip, cold roll heavy, over 25%, and then box anneal. It should be noted that the majority of deep drawing steel under 16 gauge made by the strip process is cold rolled to gauge and then box annealed to obtain the proper ductility while the hot rolled sheets rolled to gauge on the hand mills must be normalized to obtain a deep drawing quality.

In regard to hot rolling; after the ingot is cast, if the steel is to be rolled into either hot or cold strip it is first straight rolled into slabs, and each slab after re-heating and rolling makes a band of hot strip which is coiled for cold rolling. By cold reduction above 25% it becomes a coil of cold strip. In the sheet process the ingot is rolled into sheet bar, re-heated and cross rolled, re-heated and finished. In this process the finishing temperatures on the hot mill are low and probably approach the 1100° F. mentioned by Mr. Winlock. However, in the hot strip process the finishing temperatures are well above 1400° F. and most hot strip is finished high enough to obtain a completely recrystallized grain structure. The higher finishing temperatures possible on the heavier gauge strip is the reason for the uniform small grain rather than the slower cooling rate of the heavier material. A sheet mill sheet finished considerably above 1100° F. will still show a rather strained type of grain, but rarely will a hot rolled sheet show as much elongation as Figure 4, except in very light gauges.

The discussion of modulus of elasticity and stiffness is probably a little confusing to the casual reader; for, although the modulus of elasticity of steel is a constant of roughly 30,000,000 in any condition, still the ordinary user of sheet steel can "feel" a difference in the stiffness of two lots of steel and that is usually what he considers as a measure of stiffness.

As Mr. Winlock points out, stretching of a sheared edge is a very undesirable practice and will result in tearing unless the edge is ground, filed, or given a strain relieving anneal. As often as this point has been covered before, we still receive an occasional complaint from customers who try to stretch a sheared edge without proper preparation.

Many of the examples of brittleness due to large or coarse grain are not a true Stead's brittleness as the fractures show necking, are not smooth and are not at 45° to the rolling direction. Larger grained steels are more subject to localized over drawing, will cold work more rapidly and will break on subsequent working or drawing due to this. In regard to critical grain growth after annealing; this condition is only rarely encountered in cold strip sheets as the cold reduction in processing is considerably above 25%. However, in sheets hot rolled to gauge on the hand mills this condition is more liable to occur due to the number of cold passes necessary to meet the surface requirements. Subsequent box annealing will grow the grain if the strain in the metal approaches 4 or 5%.

A grain size of 1/8" at 100 X may be an ideal size for certain jobs of one steel user but somewhat larger grains are necessary for some draws and we have found that

the grain size requirements vary with the customer and the job.

Percent of elongation in 2″ on a standard test specimen is a measure of ductility, but we have found that the combination of the Olsen test and Rockwell hardness evaluate ductility as well or better and do not take as much time to make.

It is apparent from the thorough discussion of stretcher strains that it is to the advantage of both the producer and the consumer that the material be worked up within a reasonable length of time unless an inherently fine grained non-aging steel is used. As the majority of steel for deep drawing today is rimming steel susceptible to aging, most of the larger consumers are set-up to roller level or cold work the blank before drawing.

*John H. Vohr:* Mr. Winlock has presented an admirable paper and one impossible to improve, inasmuch as he has covered rather thoroughly all basic points under his subject.

However, I do believe that one very important item applicable to his subject has not been mentioned; namely, open hearth practice. I feel rather strongly that the deep drawing qualities in a sheet commence with the open hearth where such items as percentage of pig iron and scrap, quality of scrap, temperature at tapping, teeming practice, condition of molds, final quality of the ingot, and so forth, are of extreme importance. At the same time, I fully realize that many, many pages could be devoted to open hearth practice in regard to high quality sheets. It has been interesting to me to see the improvement in this practice as it has been found necessary to give more and more consideration to deep drawing steel.

Mr. Winlock stresses the importance of the temperature control feature on the hot strip mill in comparison with the lack of such control on the conventional 2-high hot mill, to which I, of course, agree. I had the interesting experience some time ago of making sheets of the same drawing quality on both strip mill and hot mill. In some cases, I went so far as to split a heat, part being rolled on the strip mill and part on the hot mill from breakdowns. The breakage on the resultant sheets from the hot mill exceeded 15% when drawn, and those from the strip mill had a breakage percentage of less than five. This experiment, to me, with other facts at hand, was quite an argument for the controlling of roll temperatures.

All of us, I believe, recognize the value of controlled temperatures in the rolling of steel, and we believe that we are in general familiar with this subject. I have been interested however, recently in the effect of the percentage of draft through the various units of a hot strip mill upon the drawing quality of steel under process. We have made repeated experiments along these lines but so far have not been able to arrive at a definite conclusion. This is due, I believe, in part to the fact that there are so many variables present; these variables being shape of rolls due to wear, temperature of the work rolls at different rates of rolling, temperature of the cooling water, and so forth.

It is interesting to hear comments on breakage caused by sheared edges, as there is no question that incipient tears are, as Mr. Winlock states, produced by any present shearing method which causes the ductility along these edges to decrease. We recently had an experience of breakage caused by this very thing. We had produced an order for which there was no explanation of any breakage occuring, since the gauge specified was such as to easily withstand the drawing requirements. However, we were very much surprised to receive a claim for breakage on this order, and an investigation proved to us that the shearing, even though of above the average quality, was entirely responsible, and we were able to correct the difficulty by annealing the edges only.

It certainly would be a benefit to the manufacturers of sheets if the press operators would fully realize the importance of treating these sheared edges with the respect due them.

I am inclined to disagree from an operator's standpoint with Mr. Winlock's statement that roller levelling to prevent stretcher strains is better than light cold rolling or skin pass. This statement would be true in my mind if the manufacturer of deep drawing sheets could be sure that the material would be drawn immediately upon receipt by the customer.

However, sheet manufacturers have no way of knowing in advance how long their sheets may be in the customers warehouse before drawing, and so I believe it to be preferable to give these sheets a skin pass or light cold roll, as by this method more time is required for the sheets to age. Of course, the ideal situation in regard to stretcher strain would be where each fabricator has the necessary roller leveller or rectifier in his process line so that each sheet would pass through this machine before reaching the presses. This method would practically eliminate all complaints concerning stretcher strains, and should eliminate considerable breakage.

Further, it is probably not possible to flatten more than fifty percent of the sheets by means of a roller leveller only, as the extra work possible through a cold mill is required to obtain a desired flatness. One more point is, of course, that the final surface on the sheet is obtained by this last rolling through a cold mill.

*W. C. Tamplin:* We feel that the paper as presented by Mr. Winlock is comprehensive and indicative of careful preparation and thorough knowledge of the subject, although we should like to present, at this time, the following comments:

As stated by Mr. Winlock, "I know of no subject which more clearly illustrates the general observation that "the art precedes the science", than the development of the deep drawing process". This not only refers to the manufacture of steel for deep drawing operations, but likewise the designing and fitting of the dies for the part to be made, together with the proper shape of the blank for the design. All are equally important to produce stampings to meet the rigid inspection of today, and to eliminate, as much as possible, the so-called hand work or metal finishing, which adds greatly to the cost of the stampings being made. Defective stampings are not always caused by a poor grade of drawing steel. We have very often noticed that the same grade of steel, from the same heat blanked on the same blanking die, will consistently work better on one die than on another—both dies being made for the same part—

especially where a right and left-hand part is required. Even though these dies are made and fitted alike, as nearly as is mechanically possible, there must be some slight difference in the dies, otherwise the forming results should be the same. The same condition is true of the metallurgy, hot rolling, heat treating and cold rolling of the steel. Quite often slight variations in any of the manufacturing processes cause unsatisfactory results, and very often differences cannot be detected by physical or laboratory examination. Usually, however, the cause of failure can be determined by close investigation of the detailed treatment or processing of the material at the mill. As stated by Mr. Winlock, very close cooperation between the metallurgist, the die maker and the mill, supplying the steel for stamping, usually meets with good results at the stamping plants. The chemistry of the steel is a carbon content of 0.10% or under, but in many cases if 0.35% manganese or under is used heavy rejections are experienced—not on account of breakage, but on account of surface conditions at points on the part being formed where the heaviest draw occurs. This part would show a coarse or open-grain surface, and would require polishing or grinding at this point on the part to obtain a uniform appearance after the part is enameled or lacquered. Rimming steel is the grade most commonly used for stampings, but for many parts Killed steel gives better results, although usually a very heavy steel loss occurs at the mills in using Killed steel.

*Cold Work:* In cold working, or cold reducing, lighter gauges, the material is reduced on an average of .054″ from the hot rolled coil to the finished thickness without annealing, or approximately between .090 to .0360. The temper (or pinch) pass is given after the annealing for the purpose of minimizing stretcher strains, and producing the proper temper for the part being made. The greater the elongation in this operation, the less is the tendency to stretcher strain—but there is a greater tendency towards buckles and breakage. In blanking, or rotary shearing, of sheets or strip for forming operations, it is very essential that the blanking dies or shears be sharp so as to avoid the heavy burred edge, on account of the tendency of the steel to tear or rip at the points showing this condition, especially where a stretching operation is involved. When excessive tearing is experienced, it is necessary to file or grind the edge of the blank, to remove the burr, or to spot anneal the edge. Our experience does not agree with Mr. Winlock that cold rolling does not increase resistance to deformation. We have found that cold rolling does resist to a greater extent, and at times, when the material has been extended in temper passing ½ of 1% more than necessary, unsatisfactory results occur, the cause for which is either buckles or a wavy appearance. If the blanks are held tight enough to remove the buckles, breakage occurs. In order to avoid breakage, it is necessary to allow more slippage, which produces the buckled condition, and it is then necessary to power hammer the part to remove the buckles, and to metal finish; consequently, in a great many cases, the proper shape of the blank is lost and the particular part does not fit properly to the adjoining parts. This one condition of cold rolling, or too great an extension in temper passing, is responsible for heavy rejections at the mills. The mills have found that in most cases material once elongated too much after annealing could not be successfully retreated by reannealing and made suitable for the purpose originally intended. This is responsible for a large tonnage of material being placed in stock as "rejects" or material suitable only for flat work or parts subjected to slight forming operations. Therefore, material marked as "rejects" does not always mean poor surface. Quite often material which has been retreated to obtain proper ductility is found satisfactory by laboratory tests, but, when subjected to actual tests in the press, it proves to be unsatisfactory. This, of course, refers mostly to cold rolled or full finish sheets. Material not having been cold rolled after annealing can be successfully retreated.

*Hot Rolling:* The temperatures at which sheets (from bars) are rolled or finished depends on the purpose for which the material is intended. Low rolling and finishing temperatures are usually necessary for best surface results. We differ with Mr. Winlock as to exaggerated grain growth in cold finishing on the hot mills. Our experience has been that material finished at low temperatures does not show exaggerated grain growth in box annealing, but will show a medium size grain for a box annealed product with very little tendency to pull coarse or "orange peel" in forming operations.

*Stretcher Straining:* Stretcher strains, or "Luder lines", have caused a great amount of trouble for both the mills and the stamping manufacturers. During the early days of the automobile industry, stretcher strains were not quite so difficult to remove or minimize to pass surface inspection—primarily for the reason that almost all sheets were box annealed and the grain size was such that the sheets would respond readily to roller leveling and minimize this defect if roller leveled a short time previous to the forming operation. It was difficult, however, to convince the stamping plants that the roller leveling operation should be done within a few hours of the actual stamping operation. Stamping departments felt that stretcher strains could be eliminated if the roller leveling was done at the mill, and the time factor did not enter into the subject; therefore, they were reluctant to equip their plants with roller levelers. I recall that roller levelers were loaned to stamping plants by some of the mills, in order to eliminate some of their difficulty, and in one place in particular, where they had been experiencing trouble to stretcher strains occurring on auto body parts, they borrowed a roller leveler from one of the mills and by roller leveling the blanks before forming they eliminated the trouble. This particular plant then decided to roller level all sheets in their warehouse, requiring more than 2-weeks time, and then to return the roller leveler. It developed later that the lapse of two days between the roller leveling and the forming operations again brought about stretcher strains. After this experience, they again borrowed the roller leveler, but placed a requisition for the purchase of such equipment for their own plant. Later on, when normalized sheets and cold reduced strip or sheets were required for these stampings, which necessitated deep drawing or severe forming operations, stretcher strains were again prominent.

Because of the small grain size of this grade of steel, the task of removing stretcher strains by roller leveling became more difficult, making it necessary to temper (or skin) pass the material after the final box annealing operation. This, in most cases, eliminated or minimized the stretcher strain condition, but the stamping concerns complained severely of more difficulty in forming due to the stiffer sheet. The shape or design of the stamping determines the amount of extension necessary to eliminate strains. The part of the stamping showing stretcher strains is that part where the least amount of drawing is involved. Other parts of the stamping, involving a greater degree of drawing, no doubt had shown this condition at an earlier stage of the draw, but the constant stretching of the material removed such defects. In a stretcher leveling machine it is possible to see the strains develop while stretching the sheet, which can again be eliminated by the continued stretching of the material. The later type backed-up roller levelers are more effective in eliminating stretcher strains than the old type levelers.

*Annealing:* Box annealing and open annealing were the systems used originally for sheets and strip. The open annealing operation was used mostly for the heavier gauges, .062″ and heavier, and usually, if annealed at sufficiently high temperatures for good stamping results, a poor surface condition resulted, caused by flaking of the oxide, which, in turn, created a mottled appearance after the sheets were pickled. Box annealing is a slow operation. In full finished sheets, or sheets of smooth surface, small quantities would be annealed at one time, especially in wide dimensions. The piles in the boxes were not over 30 inches high on account of the tendency to weld or stick together, if annealed at high temperatures. The time factor in annealing is also important, in the interest of obtaining a uniform annealing throughout the box. After the box had been withdrawn from the furnace, a great deal of time was required to cool the material for the next operation. Quite often, during summer months, a week or ten days would be required for cooling. The temperature is also important in order to avoid too large a grain structure for satisfactory forming. Box annealing was usually confined to 18 gauge and lighter, in hot rolled products, as there is a great tendency for Steads brittleness in the heavier gauges unless finished on hot mills at very low temperatures. Box annealing of cold reduced steel in sheets or strip must have careful attention as to temperature in order to avoid welding or sticking. This product carries a small grain structure after box annealing, due to the cold work performed before the annealing operation. The normalizing furnace was used more extensively before the cold reduction mills were installed. Material heat treated by this method produced a small grain structure and was more adaptable to deep drawing operations than the hot rolled box annealed product, on account of the decreased tendency to breakage in forming and a smoother surface on the stampings or bendings after the completion of the forming operations.

*H. P. Munger:* It is very gratifying to metallurgists in the steel industry to have the hearty cooperation of steel users in the solution of their mutual problems. The processing of sheet and strip steel for deep drawing has been well presented. Attention should be called to the fact that normalized sheets for deep drawing are usually also given a box anneal. This "second annealing", which is usually done at a temperature of 1000 to 1300 degrees, removes the strain set up by the rapid cooling from the normalizing temperature and produces a soft sheet suitable for deep drawing. After box annealing the carbon is present in the form of spheroidized or massive cementitie.

In connection with the various methods of testing, which are to be correlated with deep drawing properties, we agree with Mr. Winlock that a ductility measurement, such as the elongation in a tensible test, is a reliable indication of satisfactory properties. As pointed out by the author, "toughness" also plays an important part in drawing properties. Fine grained steels frequently meet the ductility requirements as measured by the elongation of the tensile test, but they usually have a high yield strength which places an unnecessarily heavy load on the dies during drawing. The most satisfactory way of determining the suitability of a sheet for deep drawing is from all of the tensile properties, including the load-deformation diagram, the hardness and an examination of the microstructure. A considerable amount of information may be obtained from the load-deformation diagram shown in Fig. 13. In addition to showing the probability of stretcher straining it shows the load necessary for plastic flow (yield strength), and the greatest load which can be supported without breakage (tensile strength). limiting values indicate the range through which the steel may be drawn. This range may be spoken of in terms of the "elastic ratio" or $\frac{\text{Yield Strength.}}{\text{Tensile Strength.}}$ The smaller the elastic ratio, the wider the drawing range of the steel.

This elastic ratio also may show the effect of the processing of a sheet. A normalized sheet will usually have an elastic ratio of about 0.75. An additional box anneal will lower this to roughly 0.65 while temper cold rolling about 1% may lower this ratio to a range of 0.55—0.60. It is interesting to note that the temper cold rolling lowers the yield strength, thereby lowering the elastic ratio and increasing the drawing range. I should like to ask the author if a similar effect is found in the McKay leveller.

The author's "kinks" are familiar to a steel mill. They are found in the form of cross-breaks during decoiling or bends in dead soft sheets. If these breaks are allowed to age before temper rolling, it is not possible to remove them without reannealing. The hardening due to aging will strengthen this portion of the steel to such an extent that it will remain as an elevation or ridge after temper rolling or drawing.

*J. S. Stanier:* In Mr. Winlock's very interesting paper, we note, and are particularly interested in the increasing importance given to grain structure and grain size, in attempting to better satisfy the stamping plant requirement and produce a more satisfactory sheet for drawing purposes. When we trace back over a period of the last ten years, in which period, rapid progress has been made in the manufacture of sheets

for stamping purposes, a great part of this progress can be rightfully attributed to the close co-operation between the steel mill, the metallurgist and the stamping plant. During this period and as a result of such close cooperation, there has been a constant search for a combination, of chemical composition and physical properties, which would blend to produce a sheet better fitted for the stamping plant purpose than had heretofore been possible.

During the period of progress, we advanced through the stages which might be narrowly designated as that of, single box anneal, double box anneal, normalized and various other combinations of the mentioned heat treatments. The result of each step brought forward the accompanying improved physical properties, and also introduced the importance of proper control of an additional characteristic, known as grain structure which was closely related to and materially effected the desired physical properties. In the early stages of normalizing, it was possible to produce a type of grain structure that gave a sheet a greater toughness than had been possible by other methods or treatments, and showed signs of greatly improving the drawing quality of sheets so treated. The accompanying physical properties, being changed considerably over those previously encountered in sheets used in the stamping plant were not conducive to the best stamping performance, due to a much stiffer temper. With the improved grain structure and grain size remaining unchanged, it was found possible through various methods and combination of treatment to adjust the accompanying physical properties to such a point that the workability of the normalized sheet was made quite satisfactory while the quality of toughness was retained.

With the present improved methods of rolling steel sheets we find at our disposal a type of grain structure and size, that heretofore would have been practically impossible to obtain, without a serious effect on other qualities of the sheet. With this condition present, it is our opinion that there remains a wide field unexplored for possibility of utilizing even greater degrees of the toughness quality, providing the accompanying physical properties can be adjusted, as has been done in the past.

In arriving at the proper grain size for any particular stamping, Mr. Winlock's reference represents the splendid work that he has carried on in this field. This work is probably foremost in the research of sheets for stamping, especially as pertaining to grain size and its importance. The disadvantages, connected with use of various grain sizes other than those now accepted as being satisfactory, in our opinion can be overcome and the advantage of grain size, now known to be troublesome, will be realized.

In summary, we believe that there is considerable to gain in stamping quality, as well as the closely related phenomena of stretcher strain and ageing, by the constant search for, more favorable physical properties such as; increased elongation, greater spread between elastic limit and tensile strength, and the proper grain size to promote these properties.

*Joseph Winlock:* I should like to thank Mr. Kerschbaum, Mr. Vohr, Mr. Tamplin, Mr. Munger and Mr. Stanier for their very valuable discussions and for their kind remarks. There is little that requires further comment except perhaps to emphasize some of the additions which they have so kindly made.

As Mr. Kerschbaum points out, the question of modulus of elasticity is a confusing one. The significance of this property of metals is perhaps of greater importance to those who design the stampings than to those who make them. I feel, however, that a clear understanding of this important fundamental property would help to remove the doubts which sometimes arise in the steel mill and press shop. As Mr. Kerschbaum emphasizes, the ordinary user of sheet and strip steel can "feel" the "stiffness" of the steel. This can be done, for example, by bending the corner of a sheet with his hands. The "stiffness" which he feels is the resistance to *permanent* deformation which really is the load required to exceed the yield strength of the steel. This is the interpretation of Mr. Tamplin when he says he does not agree that "cold rolling does not increase the resistance to deformation". I want to point out, however, that there is a fundamental difference between the resistance to deformation and the resistance to *permanent* deformation. Cold rolling or the addition of alloys affect materially the latter, but they do not affect the former. A practical example will perhaps better illustrate this important distinction. Suppose a fender for an automobile is designed and made and then found to be lacking in rigidity, i. e., it is too "flimsy". By "flimsy", I mean that after the fender has been assembled to the car, it is found that only a slight force is required to cause the fender to sag. When the force is removed, the fender springs back satisfactorily to its original position, but the fender is clearly lacking in the desired rigidity. The point I wish to make is that the same degree of sagging would occur in the fender in question regardless of whether the steel of which it was made had been cold rolled or not, or whether or not an alloy steel had been used. To put this differently, the statement is often made that lack of stiffness in a stamping can be remedied by using a steel which has been cold rolled more more severely, i. e., by using a "stronger" steel. And the metallurgist is often called upon to supply such a steel. To do this would not in the slightest degree remedy the difficulty because the resistance to deformation as shown by the modulus of elasticity is practically the same for all steels whether they have been cold rolled or not. The metallurgist can supply a steel which would permit a greater load being placed upon the fender without causing a permanent set to take place, but the flimsiness of the fender would remain absolutely unchanged. Lack of rigidity can only be remedied by (1) changing the shape of the stamping, and/or (2) by increasing the thickness of the metal.

I agree with Mr. Kerschbaum that a "cup" test and a hardness test are useful in testing sheet and strip steel for their deep drawing properties, but it has been my experience that if more exact results are needed the tensile test has proved to be the more reliable.

Mr. Munger's comments regarding the yield strength-tensile strength ratio are of interest and importance. It is desirable, as he points out, that this ratio be low in steel for deep drawing. This is because the parts of the stamping subjected to the greatest stress can

by cold working develop only a certain load-carrying capacity. If this load-carrying capacity is exceeded, the steel will neck down and break. A low ratio of yield strength to tensile strength increases the extent of the draw into the sections surrounding those of maximum stress. That is, the lower the yield strength—tensile strength ratio the greater is the amount of metal which may be drawn in those parts of the stamping which surround the region of greatest depth in the stamping.

Mr. Munger's important observation concerning the lowering of the yield strength after *very small* amounts of cold rolling is not always realized and appreciated. Roller leveling also produces the same results. This lowering of the yield point is not usually observed because some "ageing" usually takes place between the cold rolling and the testing or use of the steel. It is because some "ageing" usually does occur before the steel is used and because of the less damage done to the ductility of the steel that I prefer roller leveling. Under the circumstances which Mr. Vohr mentions, I agree that cold rolling as a final operation is desirable.

# DISCUSSION

Following is the discussion presented on the paper "Annealing and Normalizing Auto Body Steel in Electric Furnaces" by F. T. Hague and P. H. Brace. This paper was presented before the Annual Convention of the A. I. & S. E. Detroit, Mich., Sept. 22-25, 1936 and was published in the September 1936 Convention issue of the **Iron & Steel Engineer.**

PRESENTED BY

H. P. MUNGER, Metallurgist, Republic Steel Corporation, Warren, Ohio.

J. E. SPITTLE, Ford Motor Company, Dearborn, Mich.

N. P. GOSS, Cold Metal Process Company, Youngstown, Ohio.

F. E. LEAHY, Fuel Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio.

J. WINLOCK, Chief Metallurgist, Edward G. Budd Manufacturing Co., Philadelphia, Pa.

L. SELMI, Chief Metallurgist, Great Lakes Steel Corporation, Ecorse, Mich.

P. H. BRACE, Consulting Metallurgist, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

*H. P. Munger:* The authors have presented some very interesting information on the bright normalizing and annealing of auto body steel. When these results are interpreted in terms of the manufacture of steel sheets, a number of points stand out in contrast.

In discussing the variation in chemical analysis it seems that an undue amount of stress is laid on the differences found. Steels which had the same analysis excepting for the 200% variance in phosphorus or the 400% difference in silicon, mentioned under chemical analysis, would respond similarly in a commercial anneal. It should be mentioned that plants which use an appreciable amount of scrap in their open hearth will have copper analyses considerably above 0.05% rather than lower. Although nothing has been seen in the literature regarding the effect of sulphur on drawing properties. many steel companies have a maximum sulphur limit for deep drawing steels which is within the range suggested. Copper has also been shown to be detrimental to ductility and an upper limit is usually placed in the steel specification. The differences in analysis which are found in commercial practice are well recognized by the steel industry and the processing is so designed to take care of such variations.

No very satisfactory laboratory test has been devised to simulate the action of a deep drawing die. As has been pointed out in Mr. Winlock's paper, the tensile test probably gives the best correlation with actual production conditions. It is unfortunate that the tensile test was not used as a criterion of good drawing properties. Since these steels may be fine grained, and we have no information regarding the yield strength or toughness of this material, it is difficult to properly evaluate the results given. It is interesting to note that the majority of tests reported fall within a 20 point range of Olsen values, between .390 inches and .410 inches. If, as the authors have mentioned, a range of 20 points is permissible for deep drawing materials, and our experience shows that this is approximately correct, it would appear that any of the cycles which were tried, excepting the worst ones, would produce material which would be commercially satisfactory.

One question pertinent to the discussion of annealing cycle is: How low was the minimum cooling rate experimentally used in the first cooling chamber? It has been found that the rate of cooling through the critical range has a profound influence on the grain size of normalized steel. It is well established that grain size is an important factor in drawing steels and that there is an optimum grain size. It would seem desirable to include in future work an investigation of the effect of slower cooling rates through the critical transformation range on grain size and physical properties.

What kind of a surface is produced by this bright annealing? Nothing has been mentioned on this subject and it is very important that high finish sheets be free of surface defects. It would also be interesting to know what is the power cost and total cost, including maintenance, per ton of steel normalized. In the final analysis it is cost that determines the suitability of a process for industry.

The authors are opening up a new field for the industry and it is hoped that they will continue this experimental work until it matures into a commercial process.

*J. E. Spittle:* On the first illustration Mr. Hague showed you, he pointed out the small quantity of al-

loying constituents in low carbon rim steel, especially in the column that shows the percentage of variance based on lowering amounts. This seems very large and tends to be misleading, in view of the fact that the response to heat treatment does not vary in the same proportion.

For example, phosphorus was mentioned as .005 to .014, showing 200% variance. This will not change the response to heat treatment; on the other hand chromium of .02—.05% with a variance shown of 150% will influence the response to heat treatment quite materially.

In regard to the aging of cold rolled stock—that is, the full cold rolled stock—the graph shows a definite and large variation. Tests which we have made in our laboratory, which I would say are not complete as yet, do not show any great effect on aging with a 90 Rockwell strip. However, we are continuing this check, as we had never heard of it until Mr. Hague told us of this subject. I should like to hear some comment on this from other members of the audience.

Going back to practical experience with our bell furnace. At present we are using an internal temperature of 1300 degrees. This requires a furnace temperature of 1350 degrees. This lower temperature is used to make sure of the elimination of sticking in larger coils, (weighing, we will say, approximately 14,000 to 15,000 pounds,) due to tension in coiling.

In the normalizing furnace we find the strip steel very tough, more so than from the bell furnaces. Typical physical properties are as follows: On 20 gauge strip, not skin passed, the yield point is 37,000 to 44,000 lbs./sq. in.; the tensile strength, 51,000 to 58,000 pounds per square inch; Elongation in two inches ranges from 42 to 48 percent; elongation in four inches 35 to 41 percent. The Olsen ductility we find ranges from 380 to 395. The Rockwell hardness ranges from 50 to 55 "B" Scale.

These properties show a very tough sheet, on the hard side. However, we have successfully formed rear fenders, door panels, hood sides, and back panels, but we find a special die set up is necessary. In the new furnace which is not yet in operation we hope to obtain a product which will be softer, not to exceed 40 Rockwell, with an Olsen ductility of 405 to 410 on 20 gauge strip.

In conclusion, we believe there is a place in the heat treating of steel for the continuous normalizer for parts which do not require extra deep drawing, such as front fenders.

*F. E. Leahy:* One of points stressed is the approximate cost. I wonder if the speaker from the Ford Motor Company would care to give us some relative figures on the two set ups with heat treating and normalizing?

*J. E. Spittle:* That is a question we haven't gone into very thoroughly as yet. The kilowatt cost is somewhat higher than bell annealing. That we have not definitely settled because we have various cycles of normalizing and various speeds which are not set absolutely as yet. The small furnace is rather an experimental unit. I believe the larger unit will tell us more.

*N. P. Goss:* We have been experimenting with a furnace similar to the one described by the authors since 1932. Our experience with cold rolled strip allowed to age for some time before normalizing above A-3, did not seem to have any effect on the deep drawing properties after heat treatment, and so in this respect I find that our results are in agreement with Mr. Spittle's and not with the authors. In fact our experiments show hot rolled strip cold rolled and heat treated under the same conditions, showed appreciable variation in the deep drawing properties, yet the hot rolling was carried out in the same mill.

The fuel cost of an all electric furnace is a little higher than most steel companies can afford to pay, however, this situation can be remedied by using a gas-electric fired furnace. Such a combination results in a very *low* fuel cost. In such a furnace the strip is heated to about 1400 degrees F with gas fired radiant tubes, and the remainder of the heating is carried out electrically to about 1750 degrees F. Such a combination not only reduced the cost of fuel, but the electrical heating can be accurately controlled, and this is obviously essential if uniform heating is to be maintained through out the entire length of the coil.

One important factor which the authors have apparently not considered is the effect of oxygen (in the steel) on the physical properties. It is now well established that oxygen exerts a strong influence on the deep drawing properties. If a hot rolled strip examined under the microscope shows the cemenite surrounding the ferrite grains, one can conclude that the oxygen content of the strip is quite high. It is also interesting to know that this condition is not eliminated by cold rolling the hot rolled strip and heat treating above $A_3$. After heat treatment one finds that the best deep drawing qualities are found in strip steels in which the carbide is found as sorbite or pearlite, and the distribution or location of these also seem to be important.

It seems that the oxygen content of the strip steel is just about as important as the grain size, and everyone knows that grain size is without question important.

It is usually believed that the hardness of normalized strip steels is not obtained lower than Rockwell B-55. In some instances, we have obtained Rockwell B-45 and an Olsen value of 0.43″ on a strip 0.040″ thick. These strip steels were cold rolled from 0.109″ hot rolled strip (rimmed steel). We have also tried killed steels and found that the behavior of these steels are rather erratic, although in some instances results comparable to rimmed steels were obtained.

What is needed more than anything else is a tailor-made steel especially developed for this type of heat treatment. However, some producers make better hot rolled strip than others, and the result in general show that strip steels (Cold Rolled Normalized) of the future will have unusually good deep drawing properties, and of great uniformity, which is so essential and necessary in most commercial processes.

*J. Winlock:* I have read with a great deal of pleasure, Mr. Hague's and Mr. Brace's very interesting paper. In my opinion, this type of research is of great value to those engaged in the manufacture of sheet and strip steel for deep drawing. In the manufacture of many other steels, e. g., tool steels, our knowledge is much

more complete and many excellent papers are available on grain size control, influence of alloys, etc. The metallurgy of the steels for deep drawing has not, however, been so well covered, and, indeed, it is difficult to find more than a few papers touching upon the fundamentals of the subject. I was especially interested in the curves showing the decrease in ductility when a long time had transpired before normalizing after cold reducing. It would, I think, be interesting to check this further with a more accurate test such as the tensile test.

It seems to me that it is only by such researches as this that we can really find the answer to some of the many problems now existing in the metallurgy of sheet and strip steel. At the present time the trend on deep drawing steel made by the cold reduction process appears to be away from normalizing and towards a low temperature anneal. This can be done because with large reductions by cold rolling a steel of small grain size and good ductility can be obtained. The cost of such low temperature annealing is lower than the present normalizing, and the now necessary pickling which follows. The present trend, however, does not, in my opinion, mean that with certain developments of which the authors speak, e. g., controlled atmosphere, controlled cooling rate, etc., the trend may not be back again to normalizing. As the authors point out, there are certain changes which take place in the steel as it passes through its allotropic change which are very different from those occurring in the low temperature anneal It may well be that further research will show that these changes would effect the production of a more uniform and better deep drawing sheet after large reductions by cold rolling than the present practice of a low temperature anneal. For deep drawing steel which has not been reduced large percentages by cold rolling, the normalizing process is almost indispensable.

I should like to congratulate the authors on their very constructive research.

*L. Selmi:* We have been very glad indeed to have had the opportunity to study this interesting paper.

We desire to point out, however, that in large ingots weighing 15 tons or more, segragation is excessive. At 75% of the ingot, this segregation is such as to make it unfit for deep-drawing auto body stock. In practice, from 50% to 60% of the ingot is used, depending upon the nature of subsequent drawing operations.

Figure 16 shows the hardness as a function of sulphur content with two steels higher in chromium scattering above the curve. These points should be regarded with caution inasmuch as a given amount of segregate measured by sulphur is not equivalent from heat to heat. A large number of samples having the same chrome content but different sulphurs will still show a large scatter of points when hardness is plotted against the percent sulphur.

The variables causing this scatter are also responsible for different responses to heat treatment so that a cycle producing optimum results on one lot will not necessarily yield optimum results on another lot of steel.

*P. H. Brace:* In reply to Mr. Munger's remarks, I may say that we used the Olsen test because in the situation with which we had to deal at the outset the Olsen figure was accepted criterion. We are continuing our work and expect to use stress-strain data derived from tensile tests as an additional means of evaluating our results.

Before deciding upon the cooling rate from the top temperature we worked, as noted in the paper, with various rates all the way from those obtained from a liquid quench to those so slow as to be inapplicable to continuous furnace conditions. The rate chosen was that which gave the best results, all things considered, under the conditions of our investigation.

With reference to the character of the surface yielded by the furnaces which have been installed, I may say that we are getting completely bright sheet without any scratching. This point is worthy of emphasis, because there seems to be a great deal of skepticism as to the possibility of getting a strip, supported on rollers, through a long continuous furnace without scratching. It seems that we have been able to do this.

With reference to Mr. Spittle's remarks on the Table showing the variance of the minor constituents in the steel, it should be said that this Table was set up, not to cast any aspersions on the steel makers but to show what variables might have to be taken into account. We were feeling around in the dark to see what we could find. In many cases attempts to show a relationship between ductility, for example and some one other variable yielded results which suggested that someone had fired at the chart paper with a shotgun. The findings with reference to chromium and sulphur were developed by Mr. Robinson as a result of our effort to find some order in the apparent chaos.

We thank Mr. Spittle for his contribution and to say that we will be much interested in his findings on aging of the full cold-rolled stock.

Mr. Spittle's remarks on the properties of the continuous normalized material and its applicability are appreciated and it is our hope that some of present limitations will disappear as further knowledge is gained.

The unfavorable effect of aging the cold rolled sheet prior to normalizing is, as mentioned by Mr. Goss, probably pretty closely related to the oxygen content of the steel. One might theorize to the effect that in the continuous rolling of strip the interval from the soaking pit to the final cooling bed is so short that oxygen brought into solution in soaking has much less opportunity to precipitate than in the older, more leisurely processes. Therefore, the steel contains relatively large amounts of oxygen in solid solution as it goes into the cold mill and the disturbance there due to cold rolling tends to induce precipitation of this solid-solution oxygen. Assuming that such precipitation does occur, it can be argued that in time aggregation of the precipitated oxide particles will take place, giving rise to crystallites of such size that the brief normalizing cycle fails to bring them again into solution and that the undissolved residue of oxide in some way lowers the ductility.

Mr. Goss' remarks about the effect of oxygen and the correlation of microstructure and deep-drawing quality are interesting but raise a question as to why killed steels, presumably substantially free of solid solution oxygen, should respond in an erratic manner to normalizing treatment.

Anent Mr. Goss' plea for a "tailor made steel", it will be interesting to see what changes in steel making technique come about as a result of wider use of continuous, short-cycle, normalizing processes. It is quite possible that the most favorable results will be obtained by mutual adaptation of the techniques of steel making and steel treating.

In response to Mr. Selmi's remarks we must agree as to the variance in the response to heat treatment from one lot of steel to the next. This became evident early in our work and Figure 16 in which we plotted sulphur content against hardness is one result of an effort to identify the controlling factor. We would be interested to know Mr. Selmi's views as to what causes the wide scatter of the hardness figures. We did not have opportunity to examine our specimens for oxygen and as Mr. Goss suggests in his discussion, this may be the dominant variable.

However, we have an open mind on the phenomenon. We exercised considerable care in our experimental work and at this moment our feeling is that either our Olsen machine aged in a consistent manner or the steel did. We are pursuing the subject further with another lot of steel carefully selected for us by one of our steel-making friends.

At this point I wish to acknowledge and express our appreciation of, the cooperation we have received from several members of the steel industry in securing material with which to experiment. We realize that it is sometimes quite troublesome to carry a small, special lot of steel through the large-scale processes of a steel plant without loss of identification.

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# SILVER SPADE USED TO TURN FIRST SHOVEL OF DIRT FOR ARMCO LABORATORY

▲ WITH the same silver spade that had been used to break ground for Armco's Middletown East Works Plant in 1910 and the new cold mill development in 1935, George M. Verity, chairman of the Board of The American Rolling Mill Company, turned the first shovel of dirt for Armco's new $260,000 modern research laboratory at Middletown, Ohio, December 2.

A group of 30 persons, including Charles R. Hook, Armco's president, Calvin Verity, vice-president, Dr. Anson Hayes, research director, research department heads, and representatives of the Austin Company, contractors, attended the impressive ceremonies staged amid a snow-white background.

The laboratory will replace the building so suddenly destroyed by an explosion of an undetermined cause in December, 1935.

Mr. Verity, Dr. Hayes, Mr. Hook, and W. J. Austin president of the construction company, spoke briefly.

Mr. Verity declared: "Armco has always believed in research for the essential progress so necessary for the company. From Armco's research has come a large number of new products and new processes. Much of the savings that have come to workers in the steel industry have resulted from the conscientious research efforts conducted by our employees during the past 30 years, for Armco was the first steel company in its field to conduct a program of organized research."

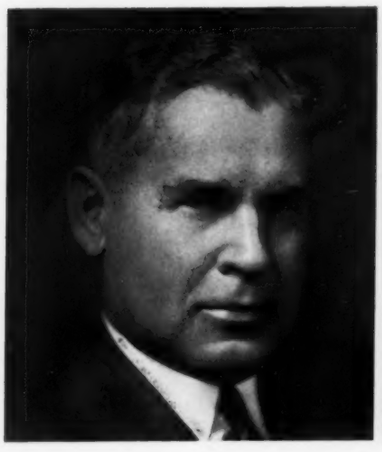
Mr. Hook declared: "The search goes on for better ways of doing things. That industrial organization which does not keep up with progress through research treads upon dangerous ground."

At ceremonies in which the first shovel of dirt for Armco's new $260,000 modern research laboratory was turned by Mr. George M. Verity, chairman of the Armco Board of Directors, December 2, at Middletown, the speakers were: Left to right in first row—Dr. Anson Hayes, Armco director of research; Mr. Verity, with silver spade in his hand; Mr. Charles R. Hook, Armco President and general manager; Mr. W. J. Austin, president of the construction company.
Mr. Calvin Verity, Armco vice president, stands next to Mr. Austin. Research department heads and other representatives of the construction company are others in the photo.

# Steel Sheets for Today's Motor Car

By THOMAS P. ARCHER, Vice President in Charge of Operations, Fisher Body Company, and R. A. GEUDER, Electrical Engineer, Reliance Electric and Engineering Company, Cleveland, Ohio.

THOS. P. ARCHER



R. A. GEUDER

**Presented before the Annual Convention of the A. I. & S. E., Detroit, Michigan, Sept. 22 - 25, 1936**

**Part 1**

## MECHANICAL PROBLEMS OF FABRICATION

By THOS. P. ARCHER

▲ SUCH revolutionary changes have taken place in the usage and methods of fabrication of sheet steel for automobile parts during the last few years that it would be impractical to attempt to give you any comprehensive picture of the problem in the short space of time allotted to this discussion. In an effort to give you at least a *general impression* of present day fabricating methods, however, I have selected a small group of typical operations, illustrations of which will be shown throughout the paper. These, in some measure, will demonstrate the major problems involved in fabricating material for the use of our industry.

Before going into a description and discussion of these problems I would like to review very briefly some interesting changes that have taken place in the last ten years, and more particularly those that have occurred since 1929.

To introduce this to you I would like to indicate at the outset that much of the outstanding progress that has been made in the design and construction of those parts of an automobile, which make for appearance, low production costs and safety, have only been possible because of the advances and improvements that have been made in the manufacture of steel sheets during this period.

Only a few years ago an automobile body, for instance, was of necessity constructed of a very large number of fabricated parts. For many years the amount of wood used in such construction far exceeded the amount of steel. Body panels were little more than trimmed sheets bent to very simple contours. Roofs were made of flimsy materials affording no protection to the occupants of the car in case of accident. Fenders were merely flat rolled sheets bent to conform to the periphery of the tire, perhaps beaded and flanged by some simple method and providing little or no protection to the car or the driver. Such things as dust pans, radiator shells and engine hoods necessarily were made in the simplest forms possible.

The first picture I will show you is that of a car which in its day was a style leader in the automobile trade. (Fig. 1.) It created a sensation when introduced, was hailed as an important advance in style technique and was widely copied. Look at it carefully. Maybe you don't realize it, but this is the famous LaSalle as it was introduced in 1928. We were quite proud of it then. We called it beautiful, but if we are honest in our present day analysis, it lacks all of those things which we consider necessary to beauty today. It is boxy, ungainly and irregular in appearance, composed

chiefly of square corners and sharp angles, and was no great shakes as a protection from the weather or accidents.

Contrast this for a moment with the new types of construction which have completely changed the appearance of cars that have been produced during the last two or three years. Here (Fig. 2) is one of the style leaders of 1936. Note the differences. Radiator shells are deeply drawn and beautifully moulded as to contour. Fenders, running boards, dust shields and all of the accessory materials, which body manufacturers call "tin ware", are solidly moulded in deeply drawn sections so as to completely house the running gear, blending perfectly into the streamline effects now being accomplished in the body structure. Body shells, which even in our 1928 style leader, were composed of a large number of more or less clumsy parts—welded, nailed and screwed together—now consist of a few sturdy solidly-welded panels gracefully moulded in intricate contours.

All of these important changes have been made in less than eight years.

The final triumph in this change of construction was the application of what has become known as the Turret Top, or all-steel roof, which we were fortunate enough to introduce to the industry three years ago.

A large part of this change has only been made possible through the development of steel processing methods, which now provide the automobile industry with a grade of material far superior to that supplied as little as five years ago. As a result of these developments we have found it possible to make revolutionary changes in our general designs, in our manufacturing methods, and in all of the general processing which goes into the construction of automobile bodies and the sheet metal parts used on the chassis.

An outstanding feature of this recent development, of course, has been the introduction of the continuous strip mills for the production of thin-gauge sheets, and the improved processing made possible by this method of manufacture. So important has this development been that entirely new fields of fabricating methods have been revealed to the designing, die-making and production division of the industry.

Fig. 1—The famous LaSalle as it looked when introduced back in 1928. Compare its boxy, ungainly and irregular appearance to the beautiful streamline body structure of one of the style leaders of the past season, shown in the upper right.

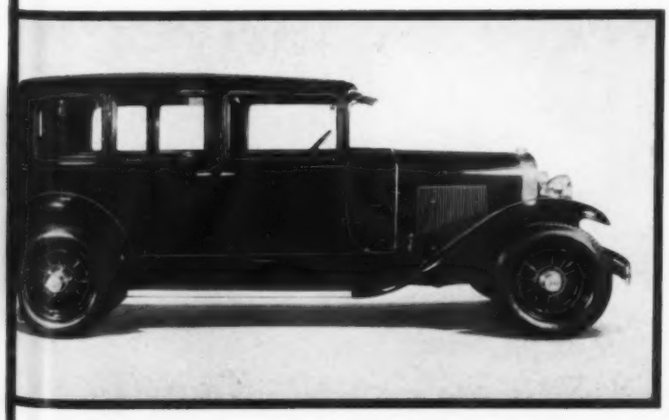


Fig. 2—The 1936 Oldsmobile, one of the style leaders of the past year. Note the marked advance made in body style in less than eight years. (See figure 1.)

To a gratifying degree many of the old limitations, which shackled the producing organizations, have been eliminated. Momentous improvement has been obtained in the uniformity of gauge, uniformity of temper, flexibility of temper control to meet varying conditions, and in surface finish. Generally speaking sheets produced by this new process are reasonably free of visible defects such as blisters, floppers, roll marks, pincer marks and charcoal pitting. So great has the change been that our rejections and breakages in present day operations, which are infinitely more severe than any operations attempted five years ago, have been reduced to an average of between 3 and 4%. In the old days a particularly bad part would develop breakages and rejections up to as high as 30%.

I am going to try to illustrate for you some of the interesting things that occur in the fabrication of steel in our industry by showing you a few of the processes which are now in daily use.

Before looking at these parts I would like to have you understand that the automobile industry is by all odds the largest fabricator of steel sheets in the world today. In consequence its problems are so closely related to those of the manufacturers of steel that each industry is largely dependent on the other for its continued advancement and development. Therefore an extremely close association between technical men of the steel industry and the automobile industry has been constantly necessary.

I would like to say to you men assembled here that the automotive industry owes a deep debt of gratitude to the operating executives at the various steel mills with which we work for their ingenuity, patience, resourcefulness and aggressiveness in attacking our common problems. The association has been gratifyingly pleasant and I believe mutually profitable.

I will take up in the pictures which you are about to see, only three processes which are now in operation in some of the Fisher Body Plants. These processes, however, include somewhere in their routine practically all of the serious problems with which we now have to contend in fabricating cold-rolled sheets.

This next picture is just a wrinkled sheet of steel. Knowing how many of you struggle to obtain flatness, continuity of gauge and surface perfection in finish, it may surprise you to know that the first thing we do is to wrinkle your beautiful sheets all out of shape.

Fig. 3—Starting at the left, the first operation makes a very sharp break in the sheet and bends it deeply over a comparatively small diameter roll, after which it is again leveled out and comes from the machine in the same surface condition as when it entered.

Practically all sheets which are to be used for drawing purposes, require what is termed in our industry as "roller processing." This processing is a development of the old roller leveller with which, I am sure, all of you are familiar. It was discovered early in the days of die development that a "worked" sheet, that is, one which had been more or less "kneeded" immediately before drawing, gave the best results. By this method breakages were reduced and stretcher strains, or surface imperfections resulting from drawing, partially eliminated. (See Figure 3).

This sheet illustrates the operations which take place on a flat sheet when it is put through a roller processing machine. You will note that the first operation makes a very sharp break in the sheet and bends it deeply over a comparatively small diameter roll, after which it is again leveled out and comes from the machine in the same surface condition as when it entered.

The net result from this process seems to be a loosening of the molecules in the structure of the steel so that the entire sheet is much more easily manipulated where deep drawing or sharp contours are required.

It is necessary to use these sheets within not more than 24 hours after going through this process or the effect is entirely lost and it becomes necessary to reprocess before using. As soon as a sheet of this nature passes through the rolling process it is trucked immediately to one of our large presses shown in Fig. 4.

This press is what is known as a triple-action deep-drawing press. The distance between the housings, that is, the width of the die space is 180 inches, or 15 feet. Some of our dies are so large that we can just barely get them between these housings. Four years ago there were no presses of this size in existence, nor had they yet been designed. This particular press weighs over 500 tons, and is capable of exerting a primary pressure of 750 tons. The upper action consists of an outer ram and an inner ram, or punch, and a third action is housed in the base of the press and operates during the "dwell" of the first and second actions, which are housed in the upper part of the press.

For your information we have in the Fisher Body Division of General Motors alone 35 of these giant presses, representing an investment in this one piece of equipment in excess of $5,000,000. These presses are ordinarily timed to operate at a rate of about 280 strokes per hour, and are controlled entirely through air clutches and generally require four men in attendance, two on either side. Each man is supplied with two palm air-valves and all eight valves must be depressed simultaneously in order to operate the press. The closing of any one valve stops the press instantaneously. This feature has been one of the most successful safety devices which we have been able to develop for an operation of this character.

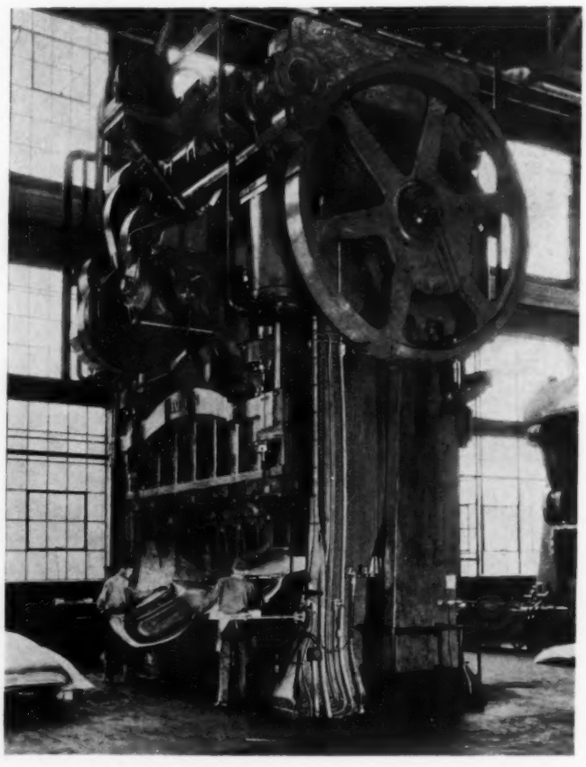
Crews operating such machines have become quite proficient and we have many crews which have been able to maintain throughout the day as high as 95% efficiency in their operation on the largest stampings.

It is infrequent that these large presses are required for anything but the first or "drawing" operation on a particular part. Subsequent operations, such as trimming, flanging, spanking, piercing, are generally performed on a simple type of press having only one action,—and which are known as single-action machines. These range in size from presses having a capacity as great as the triple-action shown, down to small piercing presses weighing only a few hundred pounds.

We will now show you (Fig. 5) a sheet of steel ready to be put through the type of press at which we have just looked. For the purpose of illustration we have checker-boarded this sheet to show the effect of forming and drawing. The lines on the blank are both perfectly straight and parallel.

You will also note that the sheet has been sheared on one corner. This shearing operation is performed

Fig. 4—This is a triple action deep drawing press. Fisher Body Company alone use 35 of these representing an investment in excess of five million dollars. These operate at the rate of about 280 strokes per hour; are controlled entirely by air clutches and require four men in attendance, two on either side.



on all irregular shapes, or blanks. The purpose for this is twofold, i.e. stock saving and to provide a means of controlling the sheet in the dies, as I will show you in the next picture.

Fig. 6 shows a stamping made from the sheet you have just seen. It has many interesting features. In the first place note the distortion of the parallel lines both horizontally and perpendicularly. This, I believe, will give you a reasonably clear picture of the amount of work that has been done in this operation. It illustrates what is known as the "first draw" in a panel which will eventually be the rear quarter of somebody's automobile body and is known to us as the quarter panel.

This is probably the most difficult panel to produce in our entire series. I don't mean that we do not have some others that are extremely difficult, because all panels as now manufactured for automobile body construction present very complex problems both to the die maker and the steel maker.

I sometimes think it is unfortunate that we have no die makers or steel makers among our designing engineers. I am sure if we had, many of the turns and curlicues, which make headaches for all of us, would be largely eliminated. Fortunately for the advancement of the industry, however, our designing engineers have a disgusting habit of developing as many problems as they can devise and then saying to those of us, who produce the steel and the parts, "It's your baby now. Let's see if you can make it."

There are two points on this particular panel which I think will be of interest to all manufacturers of steel. The "draw", which this represents, is the job in which we are most vitally interested in all stampings, as all of the remaining operations are comparatively simple after we succeed in getting the major contours developed in the first operation. I would like to call your attention particularly to the beads which you will note on the flanged part of the panel, and which continue irregularly entirely around it. You will note that in one place there is only one bead and in others there are two. As a matter of fact on the die which made this panel there are in some places three such beads. These beads perform one of the most important functions in die operation.

At the first closing of the press, that is, when the outer ram strikes the lower die, these beads are deeply impressed in the blank sheet of steel. They are included in the die for the purpose of gripping the steel on all sides when the strain of forming it is put on by the punch. The amount of strain exerted by these parts controls to an astonishing degree the final impression which will be made by the punch. The punch, you will understand, is the one part of the die which has all the necessary contours of the final panel incorporated in it.

After the flat sheet is gripped by these beads the punch then begins to function and pushes down through the panel and drags the steel over these beads. As it continues to drag, the die may be so designed that the steel will be permitted to slip over one or two beads, leaving only one to grip the metal. In other words, the amount of strain which is put on the steel by the punch is controlled entirely by the action of these beads.

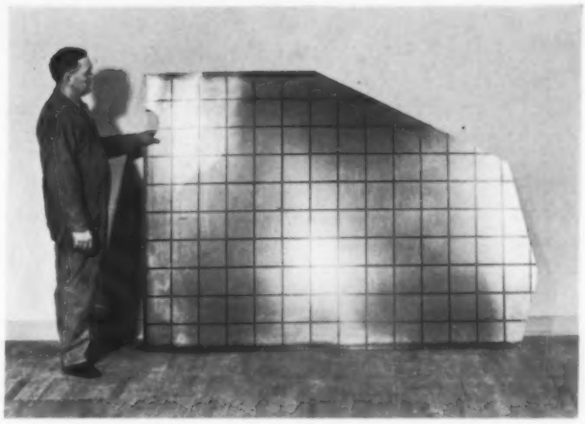


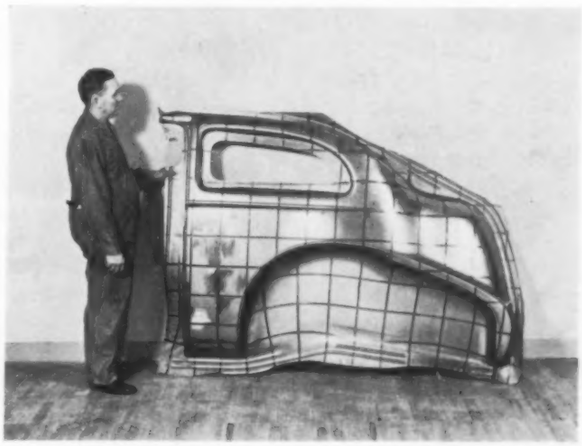
Fig. 5—A sheet of steel ready to be put through the type of press illustrated in Figure 4. This sheet is checker-boarded to show the effect of forming and drawing.

You will note from this picture that in several places only one bead shows in the final stamping, but the steel in each case has been dragged over one or two, and sometimes even three additional beads. In the development of a die the determination of just what amount of pressure must be put upon a steel blank to properly control the flow of this metal is the most delicate and difficult operation which we have to perform.

It is a very necessary part of our processing that the gauge of the panel, such as is illustrated, is not reduced appreciably in a stamping operation of this nature. It is also necessary that surface texture of the steel be maintained and the finish undisturbed. Dies on which panels of this sort are drawn are polished to a mirror finish so that in the final processes it is not necessary to file any of the surface of the panel to produce a finish, as such filing would reduce the strength of the part and consequently weaken the entire structure.

You will note at the bottom of this panel that an extremely deep draw has been made, which represents what we call the "wheel house". If you will look carefully at this you will see scratches about 10″ from the bottom of the panel. The scratches in the steel

Fig. 6—This shows the same sheet illustrated in Figure 5 and will give you an idea of the amount of work that is done in the one operation known as the "first draw".



were caused by the beads and all of the steel in the wheel housing proper has been drawn over these beads to form the deep section as indicated.

In this next picture (Fig. 7) I am going to lay this panel down on its side to show you the depth of this draw and the amount of care and skill in die construction which has been necessary to maintain the unbroken surface of the steel without any undue wrinkling, or breaking, which would impair the finished part.

Practically all of the flanges which are shown on this panel are later trimmed off, leaving only a perfectly finished piece of steel as is illustrated in the next view.

Fig. 8 is a finished quarter panel, ready for application to some automobile body after having gone through all the final operations, such as re-spanking of the wheel house, trimming of the entire flange, turning of the flanges of the window opening and door openings and the piercing of holes for moulding application, have been performed.

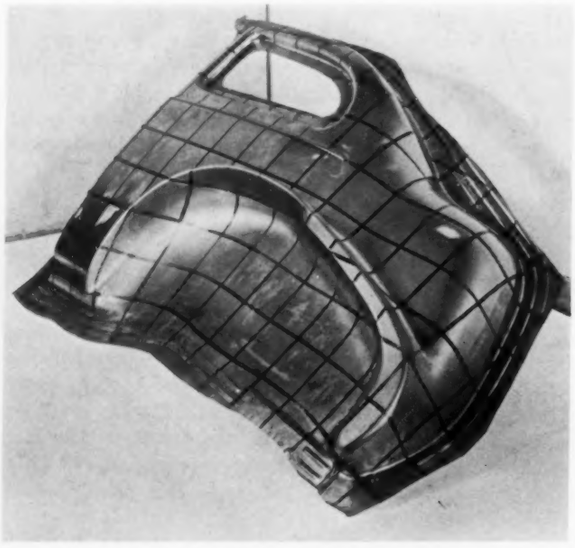


Fig. 7—Side view of the same panel that is shown in figure 6. Note the depth of the draw.

I have taken considerable time to explain this particular process for the reason that this single panel has inherent in it virtually all of the problems involved in the manufacture of any deep drawn stampings which go into automobile construction.

Such parts as fenders, radiator shells, hoods, cowls, roofs, doors and back panels all go through some such processing. Some of these panels require as many as 25 different press operations, while some of them are completely finished in two or three.

We now move to what to us has been the most important development in automobile body construction (Fig. 9) in recent years, that is, the production of all-steel roofs, or the Turret Top as it is known in our product.

I am showing you here the blank out of which this part is formed. This we have also cross-hatched and trimmed at the proper points to meet the die requirements. This blank is 72″ wide and the dies in which it is formed weigh upward of 60 tons.

Fig. 8—This is a finished quarter panel, ready for application to some automobile body.

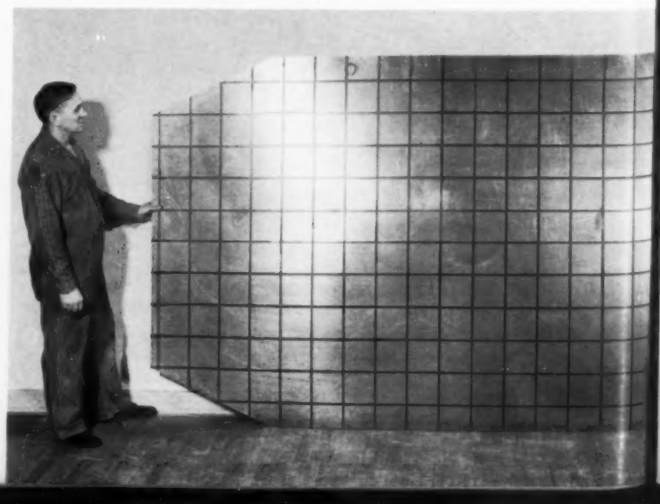
In this next picture (Fig. 10) is the Turret Top itself. To manufacture this five years ago would have been absolutely impossible unless it was pieced together of a number of smaller pieces, which would have been both impractical, prohibitively expensive and unsafe.

The actual manufacturing of the Turret roof is comparatively simple. There are only three operations required. The "draw", which we have illustrated here and the flanging and trimming operations. Its complications came in the size, finish and drawing qualities of the steel required, the magnitude of the presses required and the size of the dies needed to perform these operations. None closely approximating their size had ever been attempted until pioneered by our organization.

I want to add to this, however, that none of these things would have been possible had not the developments in steel processes and finishing kept tempo with the requirements of our advancing designs, and without the material you have given us to work with this momentous and valuable development in safety and appearance would not have been attainable in the modern automobile. We believe it is the most important single advance in body construction since the introduction of the motor car.

You will note in the illustration that many of the same characteristic changes have taken place as in the quarter panel shown before, although they are not as severe or pronounced. The same beads have been used to control the metal flow and the same type of distortion has taken place.

Fig. 9—The blank out of which all-steel roofs (Turret Tops) are formed.



The next illustration (Fig. 11) is the finished Turret Top ready to be welded to a complete body. If you will note carefully you will see that there are only four points at which this is welded to additional panels, and when that operation is completed the entire shell of present day bodies is a completely homogeneous unit.

Now the two body panels which I have shown you serve to illustrate the general type of problems which are continually before us in every operation performed in automobile construction where sheets are used. From these, I believe, you should be able to grasp something of the general nature of the fabricating problems involved.

It might be interesting for you to know that the industry last year used approximately 1,130,000 tons of cold-rolled sheet stock for these and similar parts which go into automobile construction. In addition it used about 900,000 tons of hot-rolled sheets for interior parts requiring no finish, making a total of some 2,030,000 tons consumed during the last production year. This is exclusive of the steel which went into the chassis proper. Quite a sizeable business.

I am going to turn now to some different types of operations, which are an extremely important part of our industry, and present in their own way just as many problems as the large panels already illustrated. The more impressive features of the automobile are the large chassis and body parts. There is, however, a tremendously large industry which is engaged solely making small parts for usage in automobiles. This is the hardware or accessory industry.

After an automobile body has been built from the type of stampings which were illustrated, it only becomes useful when it is trimmed completely for use. This involves the use of an astounding amount of small parts and miles of channels of various sections. These channels are formed from cold-rolled strips of varying gauge, and are put to many uses, such as sash channels, gutters, drip mouldings and trim or garnish mouldings. There are also numerous other parts, such as locks, hinges, robe rails, window regulators, deck lids, glove boxes, ash trays, tail lights and dome lights, produced in this industry.

I am going to show you just a few of these channel parts which are produced in our Ternstedt Manufacturing Division, and which present some problems to the steel maker.

I am showing in this next picture (Fig. 12) a few representative steel sections which are produced by a rolling process. The material that goes into these parts has physical properties similar to deepdrawing sheet steel.

Illustration No. 1 (upper left)—is a section of the curtain roller tube which is interlocked quite intricately.

Illustration No. 2 (upper right)—is a channel for the support of the window glass.

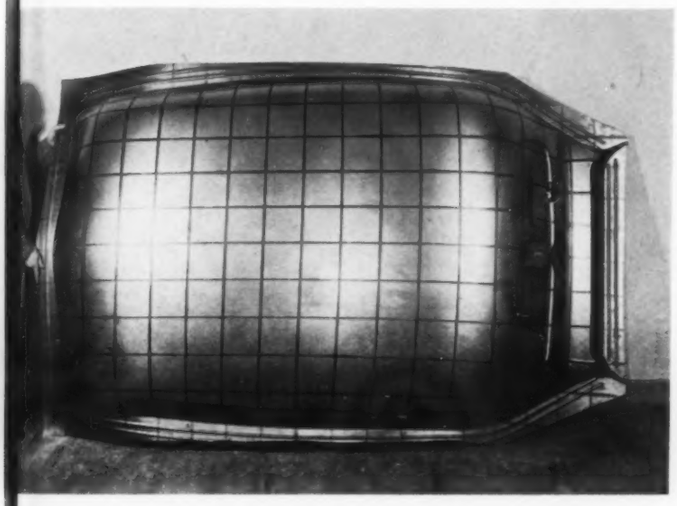
Illustration No. 3 (lower left)—is a section of the garnish moulding, or trim moulding, which is used for the interior finish of the window openings.

Illustration No. 4 (lower right) is the drip moulding attached to the Turret Top roof.

All of these shapes are produced in a continuous rolling operation. That is, the flat strip stock is started in at one end of the machine and comes out of the other end completely formed without any intervening operations. These are all primary operations and are generally the first step in the production of many intricate parts. Several hundred similar shapes are included in our daily processing.

I will ask you to keep in your mind illustration No. 3 from which garnish mouldings are made, and also illustration No. 4, as I will show you a little later on some of the things we do to the garnish moulding sections and in a later picture just how this drip moulding is processed in the rolling machine.

This next illustration (Fig. 13) is the machine on which such sections are rolled. You will see here the cold-rolled strip in coils where it is fed into the machine



10—The Turret Top. To manufacture this five years ago would have impossible unless it was pieced together of a number of smaller pieces.

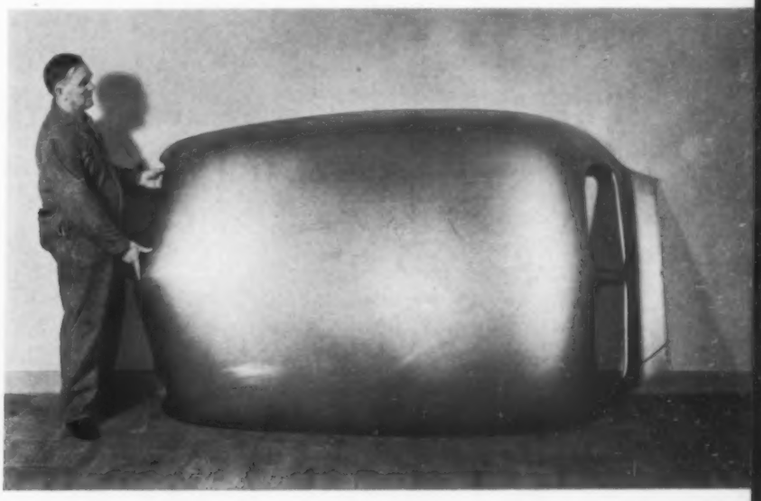
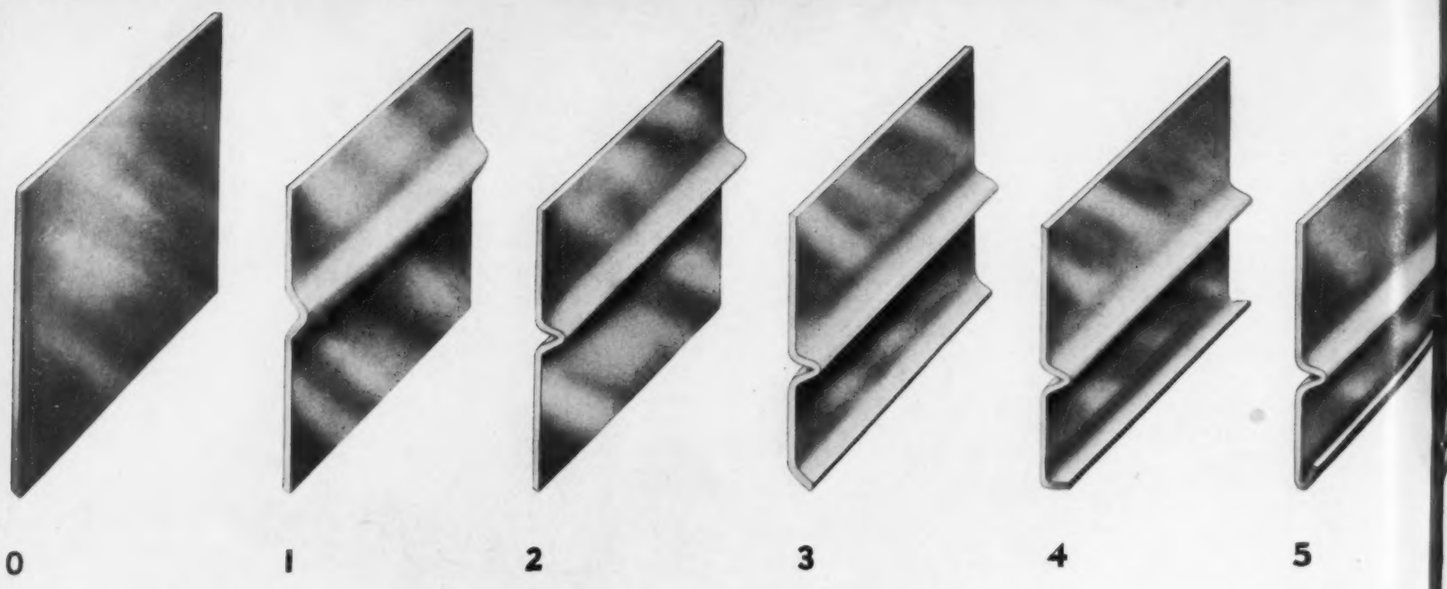


Fig. 11—This is the finished Turret Top ready to be welded to a complete body. Note that there are only four points at which this is welded to additional panels.




and you will further see that there are eight sets of rollers, each performing a part of the operation on the particular channel that is being formed. The first set of rollers are the breaking rolls, and each successive set gradually nurses the steel into shape until it reaces the desired form. The degree of accuracy which we are able to obtain in this process of manufacturing is quite surprising.

This particular machine happens to be equipped with an automatic seam-welder, which welds the juncture of the channel edges in a continuous process. The final device at the further end of the machine is an automatic cut-off, which operates somewhat in the same way as a flying shear and cuts the channel to any desired length for subsequent fabrication.

In this next illustration (Fig. 14) I am showing you just what takes place in the production of the drip moulding, which is one of the more complicated forms, in each one of the successive rolls in the machine you have just looked at. It illustrates that portion of the forming operation that is performed by each set of rolls until the final operation is completed.

Illustration 3 in Fig. 12, to which I called your attention in the section views, represents the garnish moulding, or trim moulding, which goes around each window opening on the inside of the body. This has to be made in irregular forms as each window has its own peculiar shape. To these mouldings panels are frequently added to improve their appearance, and the finish of all parts is extremely important as practically all the finished pieces are either grained or highly polished.

After the section of garnish moulding comes from the rolling machine and is cut off to the proper length, it is bent to form the window contour in a machine as illustrated here (Fig. 15).

The development of this particular process has presented a large variety of problems and we have spent several years in the perfection of this type of equipment. The channel is inserted in the machine as indicated and held in position by a sliding shoe which conforms exactly to the inside of the channel and maintains the size and shape during the process of bending. I said the shoe was sliding, but in actuality it is stationary, and the moulding is carried around by the revolving form in the center, which represents the exact contour of the window which the moulding is to trim, and is forced into shape by the shoe which is so designed as to maintain a constant pressure in the channel.

In all manufacturing processes both in the sheets and parts we have a large variety of welding operations.

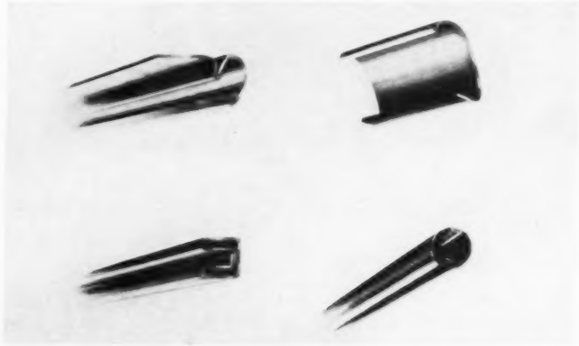
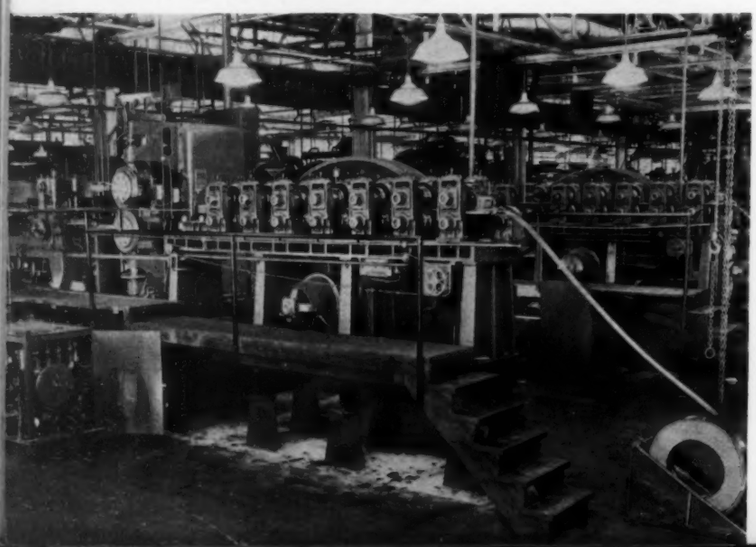


Figure 12—A few representative steel sections which are porduced by a rolling process. The material that goes into these parts has physical properties similar to deep drawing sheet steel.

Fig. 13—Machine used to roll the steel sections illustrated in Figure 12. This machine is equipped with an automatic seamwelder, which welds the juncture of the channel edges in a continuous process.



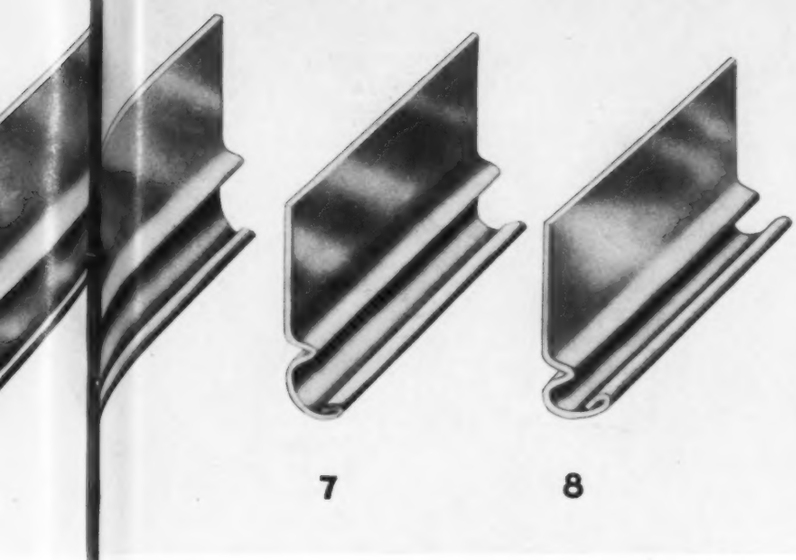



Fig. 14—This illustrates just what takes place in the production of the drip moulding, which is one of the more complicatedforms, in each one of the successive rolls in the machine, shownin Fig. 13.

In this picture (Fig. 16) you will see the moulding having the two ends welded together to complete the final contour.

And in this last illustration (Fig. 17) I am showing you the finished part after innumerable further operations, such as re-forming, polishing, graining and piercing, have been performed. At this point it is ready to be put into a body and some day perhaps one of you may be gazing through the particular window around which this garnish moulding has been installed when you buy your new car.

I know you will realize that I have touched only slightly on a few of the mechanical problems involved in the fabrication of our parts, but I cannot close this discussion without again referring to the great help and assistance to the industry that the manufacturers of steel have been.

Your alertness and resourcefulness in meeting and attacking our common problems and bringing them to a successful conclusion have been outstanding. In closing I would like to leave this thought with you, however,—we have only scratched the surface in the matter of design, construction, efficiency and cost in the use of steel in automobiles. Great as our advance has been in the last five years, it only illustrates the more vividly the possibilities of the future. Every forward step merely reveals the further progress which can be made and if our demands have been great upon you in the past, in the future they will be even greater.

Right now we need lighter steels; we need steels less affected by rust and weather conditions; we need steels of greater strength combined with greater ductility and above all, we need steel at lower costs.

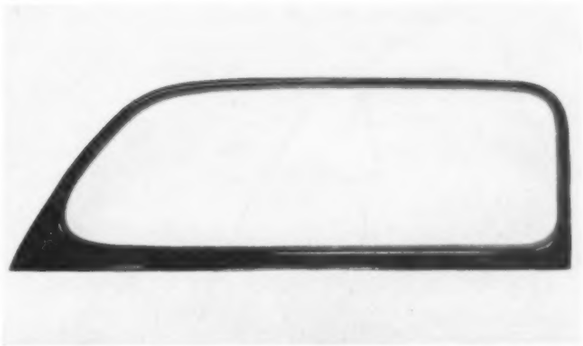
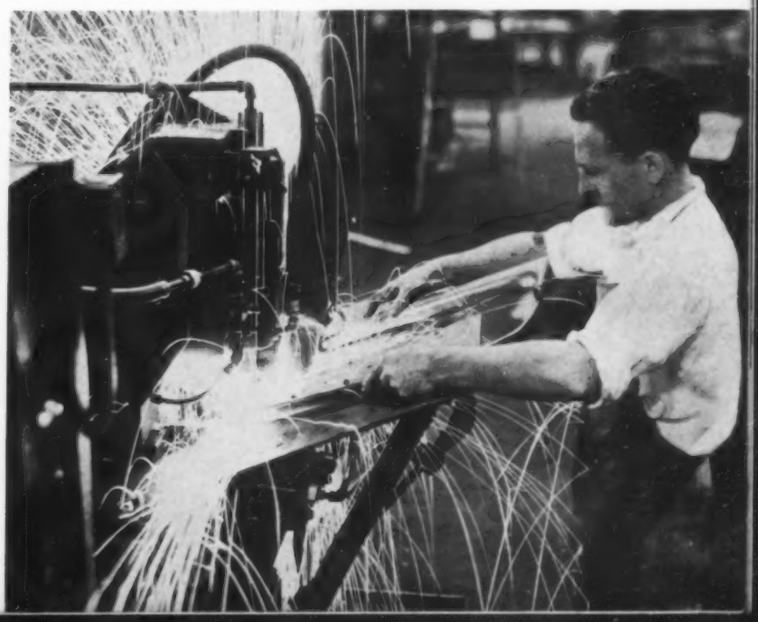


Fig. 17—The finished product after innumerable further operations such as reforming, polishing, graining and piercing.

Fig. 15—Machine used to the bend moulding to form the window contour. Several years were spent perfecting this type of equipment.

Fig. 16—This shows the moulding having the two ends welded together to complete the final contour.



## Part 2

# ELECTRICAL PROBLEMS OF FABRICATION

By R. A. GEUDER

▲ TO complete the story of fabrication of sheet steel for our modern automobiles, this electrical supplement to Mr. Archer's paper is presented. It is not our purpose to detail the complete electrical equipment on "Processing Levellers"—"Short Stroke Presses"—"Double and Triple Action Deep Draw Presses" and "Forming Machines"—as described in the foregoing paper. It is, rather, an effort to familiarize all of us with the motors and controls that are applied to these particular machines.

### I. Processing Levellers—Motor and Control

We are all more or less familiar with the processing machines used on continuous pickle lines and other similar processing "lines". While on these particular "lines" the steel is usually handled in coils, the cold working action of the processing uncoilers and the processing levellers is identical, although the steel is fed to the processing leveller in sheet form. The demand on the leveller's motor and control is a little easier here than in the pickle lines. The processing machine motor on the pickle lines must rapidly accelerate and decelerate in addition to steady running, while the processing levellers need only run continuously at a maximum speed consistent with the product and the loading on the machine.

Direct current adjustable speed motors may be used but many of these levellers are driven by four-speed, constant torque, alternating current motors, ranging up to 50 and 75 hp. at the high speed. These motors are started and left running usually at high speed. The lower speeds are very necessary for adjustments and new set-ups but are rarely used for production.

The processing roll is raised and lowered for each sheet. To accomplish this movement, a high torque special rated motor drives a crank through a suitable speed reducer. For some schedules which call for fairly short sheets, the processing leveller may handle as many as 20 to 25 sheets per minute. For each sheet the processing roll must be raised immediately as soon as the sheet is gripped in the pinch rolls on either side of the processing roll and as soon as the sheet has passed on through the leveller the processing roll must be quickly dropped to be clear for the next sheet. Therefore, the processing roll lift motor may have to start 40 to 50 times per minute. Special torque motor with low inertia rotors are used in frame sizes whose nominal rating is 5 hp. The control provides automatic starting of the processing roll lift motor and a limit switch stops it with a brake after the crank has rotated a complete 180°.

### II. Short Stroke Presses—(a) Motors

The press has a flywheel of such capacity that by slowing down 10% it will give up sufficient energy to accomplish the work. In other words, there is a certain stored kinetic energy in the flywheel when it is rotating at its maximum speed. When this flywheel is slowed down, it gives up this energy. Horsepower is a function of energy and varying inversely with time. Therefore, if we dissipate the kinetic energy of the flywheel in a given time, we will have developed a certain horsepower. However, if the energy is dissipated in half the time, we shall have developed twice the horsepower Short stroke presses do slow down their 10% in speed very rapidly and consequently deliver peak horsepowers.

The "punch press" motor which drives the flywheel has two functions. It must allow the flywheel to slow down and deliver its peak horsepower and then the motor must re-accelerate the flywheel to its original full speed. (See Figure 1.) When the flywheel is up to speed, the only load on the motor is friction load and that is a relatively small proportion of the capacity of the motor.

The punch press motor is a motor, therefore, with about 9 to 10% slip so that it will slow down 9 to 10% with the flywheel before it assumes full load. Now then, as soon as the work stroke is done, the motor will re-accelerate the flywheel and re-establish its kinetic energy preparatory to the next work stroke.

FIG. 1

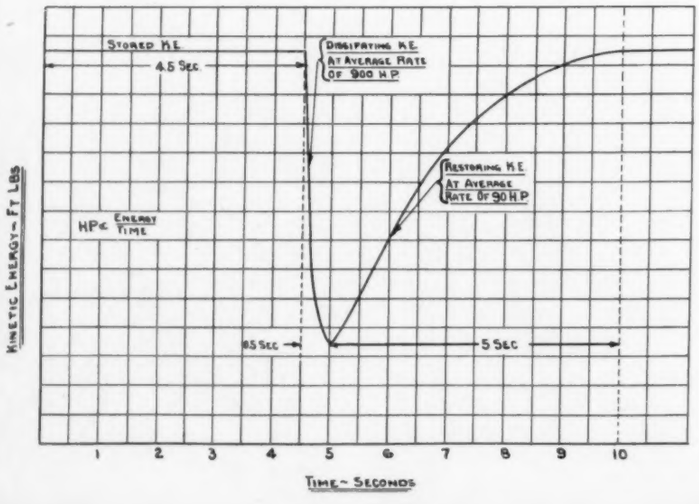
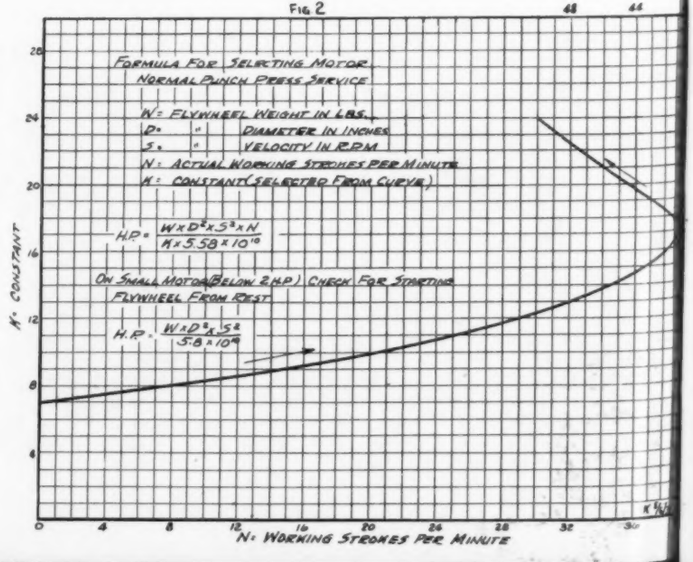

STORED K.E.
4.5 SEC
DISSIPATING K.E. AT AVERAGE RATE OF 900 H.P.
RESTORING K.E. AT AVERAGE RATE OF 90 H.P.
HP = ENERGY / TIME
KINETIC ENERGY - FT LBS
.5 SEC
5 SEC
1 2 3 4 5 6 7 8 9 10
TIME - SECONDS

FIG. 2


FORMULA FOR SELECTING MOTOR NORMAL PUNCH PRESS SERVICE
W = FLYWHEEL WEIGHT IN LBS.
D = " DIAMETER IN INCHES
S = " VELOCITY IN R.P.M.
N = ACTUAL WORKING STROKES PER MINUTE
K = CONSTANT (SELECTED FROM CURVE)
H.P. = W x D² x S³ x N / K x 5.58 x 10¹⁰
ON SMALL MOTOR (BELOW 2 H.P.) CHECK FOR STARTING FLYWHEEL FROM REST
H.P. = W x D² x S² / 5.8 x 10⁹
K CONSTANT
N = WORKING STROKES PER MINUTE
0 4 8 12 16 20 24 28 32

As soon as the flywheel has reached its original speed, *but not before*, the press is ready to do its work again. (See Figure 2.)

What we have done is to make nature do a very hard job for us—delivering a peak horsepower during a very short interval of time. What our motor has done is to return the favor—replacing the energy over a relatively long time at a reduced horsepower rate.

If, instead of using a motor with high slip of 9 to 10% we had employed a low slip motor of about 2 to 3% slip, we would be penalizing our electrical equipment. (See Figure 3.) In this case, as the flywheel attempts to slow down and deliver its energy, the motor almost immediately begins to assume full load and as the flywheel slows down further the motor may draw peaks of 2 to 3 times normal current, disturbing the power line and overheating the motor. Hence, the punch press motor with its 9 to 10% slip will result in a smaller motor, less heating in the motor, less disturbance on the power lines and probably a better overall power factor and efficiency.

Short Stroke Press Motor sizes ranging up to 75 hp. and above are operating successfully.

### (b) Control

The control includes a starter for the punch press motor, a clutch between the flywheel and the press and a brake to stop the press.

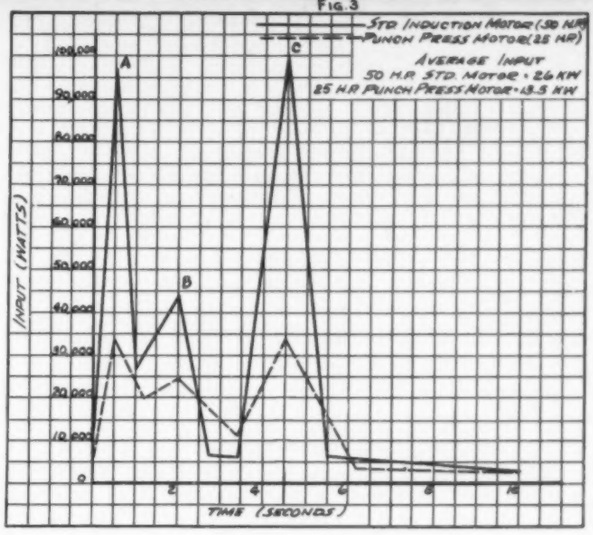
The starter for the press motor is either across the-line type or reduced voltage, depending on the size of the motor or the policy peculiar to its particular location.

The clutch is either electrically or air operated or a combination of both, where the clutch itself is air operated but the air valve is electrically controlled. The brakes come under the same classification as the clutches and are usually operated on each installation in a manner similar to the clutch—either air, electric, or a combination of both. The brake always sets when the clutch is released.

To insure the maximum of safety, the control, whether air or electric, is so arranged that all operators must have both hands on valves or push buttons before the clutch will engage. On the air operated system, the valves are all normally closed and in series so that all valves must be held open by the operators before the air pressure can operate the clutch and release the brake. If the control is electrical, the push buttons are all normally open and in series so that all must be depressed to complete the circuit to engage the clutch and release the brake. The release of any one of the control stations during the down power stroke of the press will disengage the clutch and set the brake immediately. After the power stroke is complete and the press ram or slide is returning to the top, any or all of the control stations can be released because this return is automatic and is automatically stopped by limit switches.

Press control has been steadily studied and improved. At the present time the combined air operated clutch brake with electrically operated valve is generally considered to be the latest combination and the one which is the most generally accepted.

FIG. 3




## III. Double and Triple Action Deep Draw Press

### (a) Motors

The double and triple action deep draw presses differ from the single action short stroke presses in one fundamental feature. The work stroke on the deep draw presses is considerably longer than it is on the short stroke single action. Therefore, the flywheel cannot deliver high peak horsepowers because the action is sustained for such a long duration. Let us consider a concrete case:

$$\text{Kinetic energy in ft. lbs.} = \frac{(\text{radians/sec.})^2 \times WR^2}{2g.}$$

Given Flywheel $WR^2$ = 91,800 lbs. ft.$^2$
Given Flywheel RPM = 275
Therefore, kinetic energy at 275 RPM ..... = 1,160,000 ft. lbs.
And, likewise, kinetic energy after 10% slowdown to 247.5 RPM = 939,600 ft. lbs.

Kinetic energy dissipated by flywheel when slowing down .... = 221,400 ft.
Now if this energy is dissipated in 0.5 seconds as in a short stroke single action press the flywheel will deliver at the rate of ..... $\frac{221{,}400}{550 \times 0.5} = 900$ Hp.

But if, instead, this flywheel is on a deep draw press where the power stroke lasts for an appreciable time like 5 seconds, then the flywheel energy is delivered to the work at the rate of—

$$\frac{221{,}400}{550 \times 5} = 90 \text{ Hp.}$$

Obviously this is of little assistance and the press motor must do the work.

Actual tests on deep draw presses show that the flywheel does not slow down as much as 10% during the power stroke. Therefore, under such conditions, the horsepower delivered by the flywheel is considerably less than 90 hp. and may be only 25 to 30 hp. It would seem, therefore, quite unnecessary to use high slip motors. However, punch press type motors are supplied, but for an entirely different reason. We use the high slip motors here to take advantage of their torque curve for accelerating the press when first starting up. The 9 to 10% slip semi-high torque motors have the

best ratio of average accelerating torque to the ampere and hence will accelerate a given mass more efficiently than a standard low slip motor. Moreover, on the larger presses, the setting of the dies is a delicate procedure and the dies are expensive. The clutches, while they are constantly improving, are not particularly designed for repeatedly rapid engagement and disengagement which is necessary for small increments of slide and bed travel when the press motor is running at full speed. The operator, in order to get a reduced speed on the press, starts the motor and throws off the power when the motor has reached about half speed and then closes the clutch. The service is extremely hard on the motor and will, if continued for long extended periods of time, overheat the motor. Reduced voltage inching will reduce the abuse of the motor.

The most recent innovation on the application of larger motors to Deep Draw Presses is the use of two speed, two winding, constant horsepower motors. The lower speed, as for instance 900 r.p.m. (synchronous), is used for deep draws where the higher speed of 1200 r.p.m. (synchronous) would move the dies faster than the metal could "flow". It is important to state here that for the inching service for die set-up, the use of the lower speed winding rather than the higher speed winding will appreciably reduce the motor heating and power used.

Motors of sizes up to and including 150 hp. are being used with success.

The large presses all have one ram adjustment motor and one bed adjustment motor ranging in sizes from 7½ to 50 hp., high torque intermittent duty. These motors drive through an extremely high gear ratio so that it may take as long as half an hour to move the full travel. This means, of course, that by just inching the motor, the bed can be moved in almost infinitesimal increments.

### (b) Control

The control for the deep draw press motors is the same as for the short stroke press, namely, either across-the-line or reduced voltage type. Here again, to favor the inching service, the reduced voltage type starter should be used. With the time of acceleration from zero to full speed of the press being 25 to 30 seconds, everything must be done to ease the motor and control's work. Semi-high torque punch press type motors and reduced voltage starters make a good combination. The safety features are like those described under short stroke presses. The control for the ram and bed adjustment motors are reversing across-the-line starters with either "inch" and "run" or just inch buttons "up" and "down".

## IV. Forming Machines

The fabrication of molding windshield trim, gutters, etc., has begun on multiple continuous "rolling mills". These differ from the hot and cold continuous mills in our steel industry. The industry's rolling mills are primarily reducing mills. They take the bloom, reduce it to a slab, next a billet, a bar, a plate, and finally a strip either coiled or sheared into lengths. Each process has reduced the cross section and elongated the product. However, in the forming rolling mills for garnish molding (window trim), for instance, the roll pressure has a "primary function of confining the metal to maintain cross sectional areas". Each succeeding pair of rolls in the forming machine guides the partially formed strip one step further on its way to the desired shape. On these sizes of forming machines the various sets of rolls are all gear driven from one motor ranging in size 15 to 25 hp. The motor is a continuous operating motor selected to be well loaded. The only starting and stopping occurs when the tail end of one coil is being welded to the front end of the next coil. Hence, perfectly standard AC or DC general purpose type motors are applicable with such modifications of enclosures as may fit its particular location. These machines operate at speeds around 300 f.p.m. The spot welder that joins the tail end of one coil to the front end of the next coil is 40 to 50 KVA capacity.

As the formed section emerges from the last pair of forming rolls, it runs out on a slide until the front end trips a limit. This limit, frequently air-operated, engages a clutch to move the cut-off machine at the same speed as the strip. At a definite spot the shear die mechanism operates to cut off the strip and then the cut-off carriage returns to its original position, right at the delivery end of the forming machine. The motor on the cut-off machine is a normal 2 hp. at 900 r.p.m. The traverse and cut-off mechanisms are clutch operated so that the motor runs continuously.

The cut-to-length formed strips now pass to the bending machine. The clamping device is air-operated. The revolving head is operated through a clutch by a motor ranging in size from 10 to 25 hp., general purpose AC or DC.

Frequently the bending machine's head is so designed that the finished shape can be cut into two identical pieces. The individual pieces now pass on to a multitude of notching, flanging, trimming, piercing, reforming, stamping and restriking presses. Each single press has its own single function. There may be as many as ten or eleven of these presses each with a motor and control ranging from 1 hp. up to 25 hp. The controls and motors are punch press type described previously. All the various forming machines are served with continuously operating overhead monorail conveyors. 5 hp., 1800 r.p.m. motors are commonly used. These same conveyors carry these rough finished molding parts to the assembly department where two pieces are butt welded together, the weld ground off, rough polished and finally oil polished. The conveyors now transport the finished molding to the paint and lacquer departments.

It might be interesting to know the total connected horsepower on the machines required to manufacture the upper and lower rolled sections of the garnish molding. A total of 182 hp. is required from the coil that enters the multiple roll forming machine to the finished garnish molding as it enters the paint department. It is significant to bear in mind that the process above, so briefly described, but nevertheless requiring almost 200 hp. total, represents only the trim for one certain window, for one certain model car as manufactured by one certain builder. If we will but let our imagination wander, while we think of all the molding on all the models of cars as produced by the dozens of automobile builders, we will begin to appreciate the tremendous amount of mechanical and electrical equipment that is fabricating steel for today's motor car.

# The Cold Rolling of MILD STEEL SHEETS AND STRIP

**Presented at Annual Convention, American Society for Metals, Cleveland, Ohio Oct. 19-23, 1936**

By ANSON HAYES, Director, Research Laboratories, and R. S. BURNS, Research Engineer, Research Laboratories, The American Rolling Mill Company
MIDDLETOWN, OHIO

**ABSTRACT**

*The authors have dealt only with the more fundamental aspects of the problem in connection with the metallurgical phases of the discussion. Theoretical discussion includes a simplified treatment of the mechanism for reduction by rolling, with particular reference to the so-called no-slip point. Data are given to show the effects of both front and back tension on the position of the no-slip point, and the effects of such tension on the metallurgy of the product and the power required to make reductions. Stress-strain curves show the effects of various amounts of cold reduction on the shape of such curves both before and after annealing. Correlations among the amount of yield point elongation, yield point in pounds per square inch, and the grain size are shown by these curves and the photomicrographs. Under the subject of Finishing, the elimination of yield point elongation is shown to be a function of the initial amount of yield point elongation, the diameter of the rolls used for tempering, and the surface of both the sheet and the rolls. A brief discussion of both roller leveling and stretcher leveling is also included.*

▲ THE authors have undertaken to discuss those parts of the broad outline for the Symposium on the Plastic Working of Metals devoted to types and applications of equipment, reasons for their use, flow of metal, fibre and grain size resulting from cold rolling operations, and these same features for cold straightening processes. Because of the very broad field that would be involved and the length of a paper dealing with such a wide scope, we have chosen to discuss these subjects as are involved with mild steel sheets and strip. To further limit this discussion, we have chosen to deal with a few types of equipment being used most at the present time. In connection with the metallurgical phases of the discussion, we have attempted to deal with only the more fundamental aspects of the metallurgy of this one product—mild steel.

As rolling operations are carried out in practice, cold rolling sheets and strip material at essentially room temperature is a simpler process with which to deal metallurgically than is true of the hot rolling process. As most commonly practices, hot rolling is carried out at temperatures where two opposing processes are in action: One, the deformation of the metal which develops what is usually designated as "strain," and that of annealing, which has the effect of reducing the strain which deformation by the rolls is producing. The resulting strain in a hot-rolled material may, therefore, be considered as the net result of the development of strain through deformation and that of the annealing effect, which may be a simple relief of some of the strain, or of an actual partial recrystallization. Complete recrystallization, as is well known, removes much more completely the effects of severe deforming processes than do annealing operations at temperatures which are too low and for lengths of time which are too short to bring about such changes in structure.

There has been from time to time much discussion regarding the definition of hot and cold rolling of sheets and strip. Badlam[1] has defined cold rolling as "the working or shaping of a material by means of rolls at temperatures below the critical range." He defines hot rolling as "working above the critical range."

In the light of what has just been said, the authors believe that a better definition can be formulated. The cold rolling operation carried out as it is near room temperatures, leaves essentially the fully strained structure produced by the deformation of rolling. The process of rolling at temperatures in the neighborhood of 1100 to 1250 degrees Fahr., while well below the critical range, has the strain condition produced by rolling very markedly modified by the annealing effect. Viewed from the standpoint of the structural effects of the rolling process, it would seem that a better definition of cold rolling would be "rolling at temperatures sufficiently low as to result in essentially no change due to annealing of the deformed structures which result from the reduction of gage by rolling."

1. Year book of the American Iron & Steel Institute; page 352 (1930)

## HISTORICAL

Records show that cold rolling mills were used as early as 1550 for the production of bars of gold and silver. According to Badlam,[2] the beginning of the cold rolling of iron and steel as an industry may be said to date from about 1830, as at that time we find records of the manufacture and use of steel reeds by the weavers of Barmen and Hohenlimburg in Germany. These reeds were made of high carbon steel, flattened by cold rolling in exactly the same manner as is practiced in the flat wire industry today. They, as well as watch and clock springs, probably constituted the production of that period. Krupp had started the manufacture of hardened steel rolls for cold rolling steel at about this same time.

When one considers the large tonnages of cold-reduced strip and sheet steel consumed at the present time, the historical sketches of Badlam are interesting in that they show the chief uses of cold-rolled steel have risen from products such as wire for ladies' hats, hoops for the old-style hoop skirts, corset staves, clock springs, and shank steel for shoes, to sheets and strip of width of 90 inches or more with excellent surface and physical properties made in tonnages never dreamed of in that earlier period. For a most interesting detailed chronological story of the gradual process of development of the necessary elements in equipment and its operation for manufacturing cold-rolled steel and the development of markets for it, Badlam's article,[3] together with that of J. R. Adams,[4] is very good. In these references is given a clear conception of the struggle in the development of materials, machine designs, and methods of applying power, which are characteristic of our present-day steel mill units. The earliest mills were driven by water power. These were supplanted by steam. The steam engine, in turn, gave way to the use of constant-speed motors, which today have been supplanted by the highly flexible individual direct current motor.

Developments in materials used for mills and for annealing and handling the cold-rolled material are no less phenominal. Today it can be said that our present cold rolling methods of manufacturing mild steel sheets and strip are the result of a large number of contributing factors in scientific progress, in improvement of materials, and in experience.

## THEORETICAL

At the present time, equipment for cold reducing stock in the manufacture of steel sheets and strip is available, which makes use of one, or combinations of two or more, of the following methods of applying power to bring about the thinning of section:

1. All power applied to the working rolls.
2. All power applied as a combination of forward and back tension.
3. Part of power applied to rolls and part as forward tension.
4. Part of power applied to rolls, part as forward tension, and part as back tension.

In the following simplified treatment of the mechanism for reduction by cold rolling, attention will be confined to actions going on between the point of entry of the stock into rolls and that of exit. So far as the roll surfaces are concerned, this region will be called the "arc of contact."

Under the most usual conditions for rolling, there is a point within the region mentioned above for which the horizontal component of the forward movement of the stock is equal to that of the roll surface. This point will be called the *no-slip point.* Back of this point, the stock has a forward horizontal component of velocity less than that of the roll surface. In front of it, the stock has a greater forward horizontal velocity component than the roll surface. This means that back of the no-slip point, there is backward slip of the stock relative to the roll surface; while in front, there is forward slip. The rolling process of reducing the thickness of metal may, in fact, be considered as a special extrusion process.

The location of the no-slip point depends upon a number of factors, such as:

1. Percentage of reduction effected.
2. Physical properties of the metal under reduction.
3. Combination of methods of applying power, as indicated earlier, and its distribution between the various methods.
4. Coefficient of friction between rolls and stock.

In the analysis which follows, the principal simplifying assumptions made are:

1. No side spread in the stock during reduction.
2. No change in density of material.
3. The horizontal component of forward velocity is constant across the section of the stock at any point in the arc of contact.
4. The coefficient of friction between the stock and the roll surface is constant at any one point within the arc of contact.
5. Elastic deformation is negligible as compared to plastic.

In Fig. 1

Let $\theta$ = angle of contact between rolls and stock.
$a$ = angle to the no-slip point.
r = radius of rolls.
$\omega$ = angular velocity of rolls.
T = thickness of incoming stock.
t = thickness of outgoing stock.
$t_x$ = thickness of stock at no-slip point.
$V_i$ = horizontal component of velocity of incoming stock.
$V_o$ = horizontal component of outgoing stock.
$V_x$ = horizontal component of stock at the no-slip point.

Equal volumes of stock are passing the various points in the arc of contact in the same interval of time—consequently:

$$(1)\quad V_i \frac{T}{t} = V_o$$

$$(2)\quad V_x = \frac{t}{t_x} V_o$$

(3) $V_x = \omega\, r \cos a$ since this is the no-slip point.

(4) $t_x = t + 2r\,(1 - \cos a)$

2 Loc. cit. 3 Loc. cit.
4 Year book of American Iron and Steel Institute, page 115 (1924).

(5) $T = t + 2r(1 - \cos\theta)$

By combining (2), (3), and (4)

(6) $$V_x = \omega r \cos a = \frac{tV_o}{t + 2r(1 - \cos a)}$$

From (6) $a$ can be computed from r, $\omega$, $V_o$, and t. However the use of this equation is somewhat inconvenient for computational purposes. Fortunately there are simple methods of experimental procedure by which $V_x$ can be obtained.

Assume a scribe mark is made parallel to the axis of the roll. The circumference is the distance between the imprints of this mark on the stock, if no elongation on the stock occurs after it passes the no-slip point. The distance between any two marks continues to increase up to the completion of reduction in the arc of contact. However, the same volume of stock is present between these two scribe marks at all points from the no slip point to exit.

If $d_x$ = circumference of the roll.

d = distance after exit between any two marks; then

$t_x d_x = td$ = volume of stock; and

(7) $$\frac{t}{t_x} = \frac{d_x}{d}$$

From (2) and (7)

(8) $$V_x = \frac{d_x}{d} V_o$$

And from (6) and (8)

(9) $$V_x = \frac{d_x}{d} V_o = \omega r \cos a \frac{tV_o}{t + 2r(1 - \cos a)}$$

Equation (9) may be used to compute cos $a$ from the issuing velocity of stock, the linear velocity of the roll surface, and the ratio of the roll circumference and the distance between any two adjacent marks on the stock after exit. Further consideration shows that forward slip, $S_e$, between roll and stock at the point of exit is given by

(10) $S_e = V_o - \omega r \cos a$

Horizontal component of back slip at entry, $S_i$, is given by

(11) $S_i = \omega r \cos a - V_i$.

To get circumferential slip between roll surface and stock at entry, consideration of geometry of Fig. 1 gives

(12) $\frac{V_i}{\cos\theta}$ = Tangential velocity of stock at entry, and consequently

(13) $\omega r - \frac{V_i}{\cos\theta}$ = circumferential back slip between surface of stock and roll face at entry.

To show the effects of both front and back tension on the position of the no-slip point, the following data were obtained in experiments carried on with a mill where both front and back tension could be measured accurately and varied over a wide range. To calculate alpha, the following equation (9) was used:

$$\cos a = \frac{tV_x + 2rV_x - tV_o}{2rV_x}$$

Experiments 1, 2 and 3 (Table I) were intended to show the effect of no tension, front tension only, and equal pull front and back (not equal tensions front and back because strip is 30 per cent heavier on entrance side of mill; hence, unit stress is 30 per cent less.) An attempt at rolling with no front tension and 18,600 pounds per square inch back tension was futile, because the rolls would not pull the strip through under this high back tension, and roughening of the rolls would have altered the conditions of the test.

Experiments 4 through 8 show the effect of variations in front tension when no back tension is applied. Note

Fig. 1—Diagram of the Process of Reduction by Rolling.

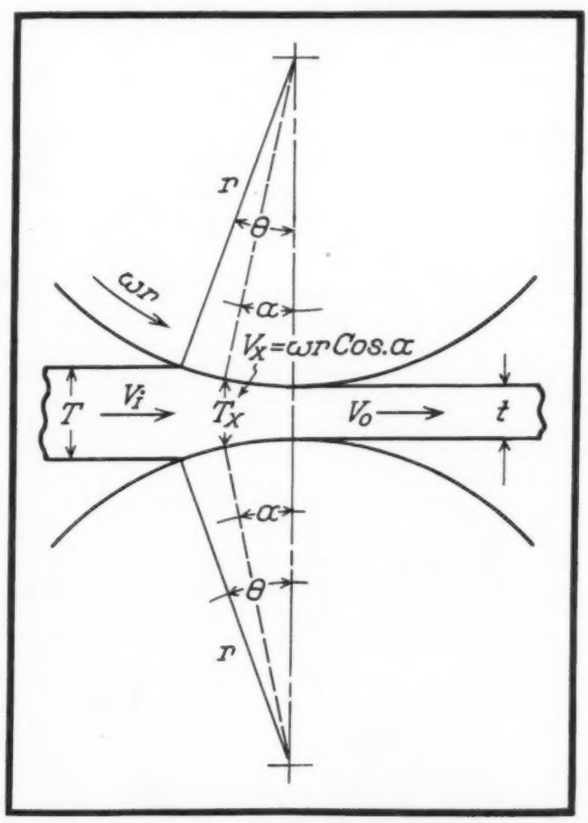



TABLE I

Effect of Variations in Front and Back Tension on the Exit Velocity and Angle Alpha with Constant Roll Speed

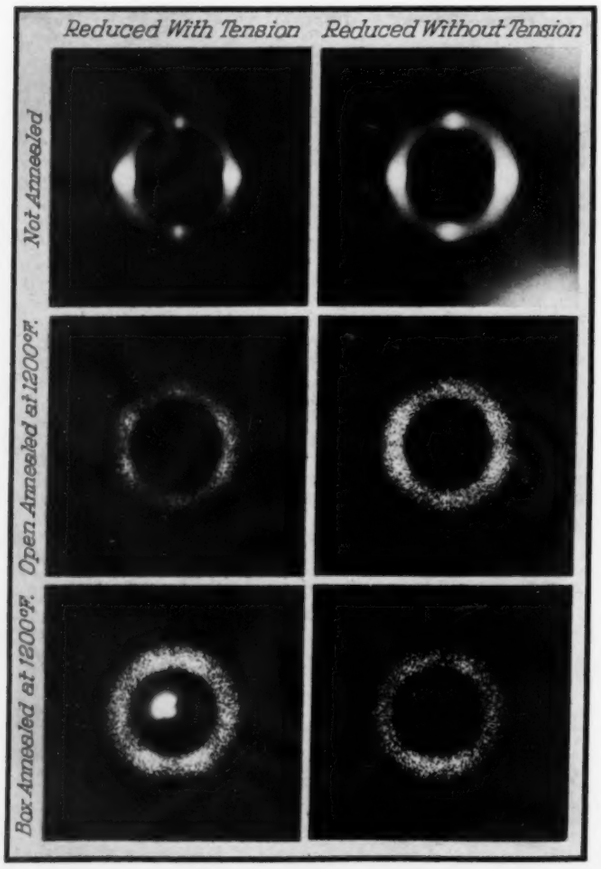
| Experiment # | Gage In Roll | Gage Out Radius | % Reduction = 2.077 | Front #/Sq. In. | Back #/Sq. In. | $V_o$ Cos Theta = | $V_x$ .99037 | Alpha Theta = 7°58′ |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.067 | 0.047 | 29.8 | 0 | 0 | 13.513 | 13.050 | 2°18′ |
| 2 | 0.067 | 0.0465 | 30.6 | 26500 | 0 | 14.270 | 13.050 | 3°44′ |
| 3 | 0.067 | 0.047 | 29.8 | 26500 | 18600 | 13.694 | 13.050 | 2°43′ |
| 4 | 0.067 | 0.047 | 29.8 | 0 | 0 | 13.513 | 13.050 | 2°18′ |
| 5 | 0.067 | 0.047 | 29.8 | 10000 | 0 | 13.658 | 13.050 | 2°38′ |
| 6 | 0.067 | 0.047 | 29.8 | 22000 | 0 | 14.060 | 13.050 | 3°24′ |
| 7 | 0.067 | 0.047 | 29.8 | 30000 | 0 | 14.435 | 13.050 | 3°58′ |
| 8 | 0.067 | 0.047 | 29.8 | 42500 | 0 | 15.200 | 13.050 | 4°57′ |
| | Roll | Radius | = 2.077 | | | cos Θ = | .99182 Θ | = 7°20′ |
| 9 | 0.034 | 0.017 | 50.0 | 40000 | 28600 | 14.655 | 13.050 | 2°34′ |
| 10 | 0.034 | 0.017 | 50.0 | 40000 | 25700 | 14.694 | 13.050 | 2°36′ |
| 11 | 0.034 | 0.017 | 50.0 | 40000 | 22800 | 14.700 | 13.050 | 2°36′ |
| 12 | 0.034 | 0.017 | 50.0 | 40000 | 20000 | 14.759 | 13.050 | 2°39′ |
| 13 | 0.034 | 0.017 | 50.0 | 40000 | 17100 | 14.890 | 13.050 | 2°45′ |
| 14 | 0.034 | 0.017 | 50.0 | 40000 | 14300 | 14.970 | 13.050 | 2°49′ |
| 15 | 0.034 | 0.017 | 50.0 | 40000 | 11400 | 15.112 | 13.050 | 2°55′ |
| 16 | 0.034 | 0.017 | 50.0 | 40000 | 8550 | 15.269 | 13.050 | 3° 1′ |
| 17 | 0.034 | 0.017 | 50.0 | 40000 | 0 | 15.699 | 13.050 | 3°18′ |

that the speed of the outcoming strip varies from 13.5 to 15.2 with the same roll speed. This means that the equilibrium between forward and backward slip has been radically changed by the application of this high front tension. Experiments 9 through 17 were made under the same mill conditions so far as roll speed and roll surface are concerned, but the use of lighter gage stock and heavier reduction (50 per cent) are involved. These data show that the position of the no-slip point, and, hence, the equilibrium between front and back tension, may also be altered by changes in back tension.

Insofar as the metallurgical and X-ray structures of the deformed metal is concerned, the X-ray diffraction patterns and micrographs shown in Figs. 2 and 3, respectively, were made on mild steel cold reduced 83 per cent, with and without tension, in three passes as follows:

| Pass | Gage In | Gage Out | Per Cent Reduction | Tension Out Lb./Sq. In. |
|---|---|---|---|---|
| 1 | 0.067 | 0.035 | 47.1 | 25,500 |
| 2 | 0.035 | 0.017 | 51.4 | 28,400 |
| 3 | 0.017 | 0.011 | 35.3 | 35,000 |

Fig. 2—X-Ray Diffraction Patterns of Mild Steel as Cold Reduced and After Cold Reducing and Annealing at 1200 Degrees Fahr. Samples Cold Reduced 83 Per Cent With and Without Tension. a—Reduced With Tension, Not Annealed. b—Reduced Without Tension, Not Annealed. c—Reduced With Tension, Open Annealed at 1200 Degrees Fahr. d—Reduced Without Tension, Open Annealed at 1200 Degrees Fahr. e—Reduced With Tension, Box Annealed at 1200 Degrees Fahr. f—Reduced Without Tension, Box Annealed at 1200 Degrees Fahr.



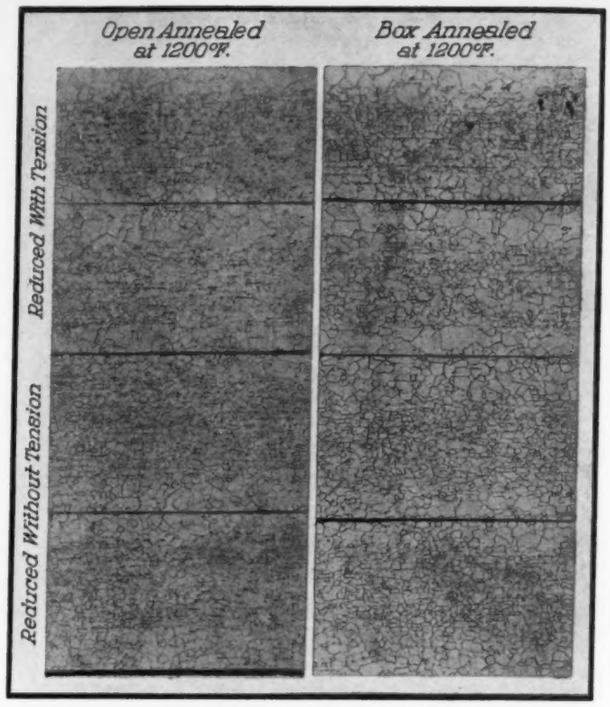




Fig. 3—Micrographs of Mild Steel. Cold Reduced 83 Per Cent With and Without Tension and Annealed at 1200 Degrees Fahr. a—Reduced With Tension, Open Annealed at 1200 Degrees Fahr. b—Reduced Without Tension, Open Annealed at 1200 Degrees Fahr. c—Reduced With Tension, Box Annealed at 1200 Degrees Fahr. d—Reduced Without Tension, Box Annealed at 1200 Degrees Fahr. Etched in 3% Nital. × 100.

The samples cold reduced without tension were made in the same steps of reduction. The X-ray patterns show no differences in the degree of preferred orientation produced by rolling with tension, and the photomicrographs show no differences in structure caused by tension rolling, either before or after annealing. Many other annealing treatments were performed on these samples, but no differences were found in rolling with and without tension.

No definite and concise information has come to our attention that shows any difference metallurgically caused by rolling all in one direction or by reversing the rolling direction each pass.

Experiments have shown that as the front tension applied is increased, the net energy necessary to reduce the strip is decreased. These tests, however, were made with a constant differential pull of 300 pounds forward per inch of strip width. Hence, as the front tension was increased from 700 to 1400 pounds per inch of strip width, the back tension was increased from 400 to 1100 pounds per inch of strip width. This increase in front and back tension decreases the screw pressure about 30 per cent, which in turn decreases the power lost as friction between the roll face and the strip. Therefore, if we consider only the net energy required to deform the metal, and disregard the higher loss of power at the brake, or economically retrieve this power, then the energy required to deform the strip decreases with higher front and back tensions. However, if the power lost at the brake is considered as "lost," the power required to deform the strip increases as the front and back tension are increased.

With increasing back tension (front tension constant

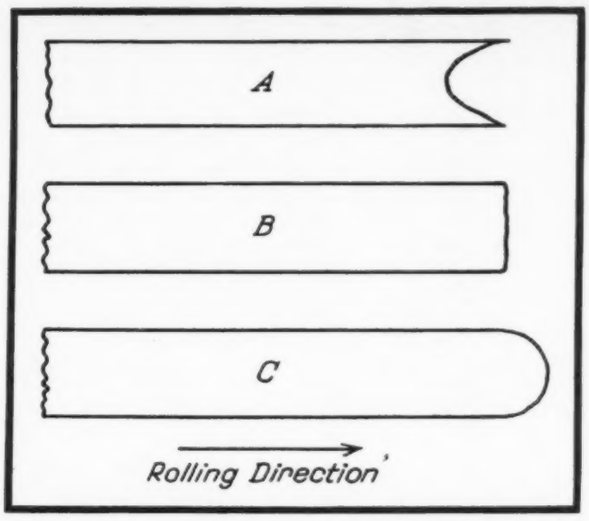



Fig. 4—The Shape of the Front End of the Stock as Varied by Light and Heavy Reductions.

at 40,000 pounds per square inch), the total energy required to reduce the strip increases because of the higher power losses at the brake. If the power lost at the brake could be recovered economically, then operation with a high back tension would be economical. Screw pressure decreases with increasing back tension, but changes in front tension with constant back tension seem to have little, if any, effect on the screw pressure.

It is obvious from the foregoing that there may be combinations of the percentage of power supplied to the mill or reel which give most economical results. These conditions depend so largely upon the physical characteristics of the product and the mill at hand that each operator has varied the conditions to suit his particular problem.

Insofar as smaller rolls decrease the screw pressure, it would be expected that decreasing the roll size would decrease the power lost as friction between the strip and the roll face, and hence, decrease the net energy required to accomplish a given reduction. Small rolls, however, must be reground oftener than large rolls.

In the theoretical treatment of an earlier section on the size of the no-slip angle in cold rolling, the assumption was made that the horizontal component of forward progress of all parts of the cross section of the stock at any one point within the arc of contact is the same. Experience has shown that this assumption is true in only very special cases. In Fig. 4 are shown three types of fronts which were obtained.

For very light cold reductions, such as are used in temper rolling, the front of the stock takes the form shown in Fig. 4A. The concave form of this front shows that the surfaces of the stock slip forward faster than do points in the stock farther from the surface. In heavy reductions, a convex front is obtained, as shown in Fig. 4C. For some intermediate reductions between those results in the shape shown in Fig. 4A and that in Fig. 4C, a straight front may be obtained as shown in Fig. 4B.

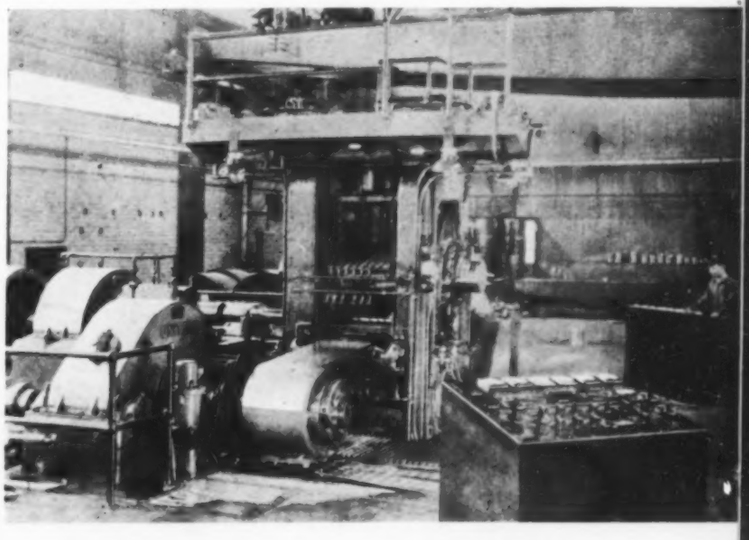
## COLD ROLLING EQUIPMENT

The type of cold mill used for a particular product depends to a large extent on the desired characteristics of the product and the equipment available at the time of the installation. Stephen Badlam has discussed these points very ably in his papers in the Yearbook of American Iron & Steel Institute, 1930, and the December, 1935, issue of *Iron and Steel Engineer*. The four types of cold reduction mills which will be mentioned are: (1) tandem mill, (2) single stand reversing mill, (3) Steckel mill, (4) cold sheet mill. The advantages of the tandem mills for reducing coils are: (1) great capacity, (2) low labor cost, although the installation cost of the tandem mill is very high. The disadvantages of the tandem mills involve lack of flexibility for rapid section changes and the fact that the stock must receive a fixed and limited number of passes.

With the single stand reversing mill (Fig. 5) less floor space is required than for the tandem mill. The single stand reversing mill also has great flexibility as to the number of passes, a lower initial cost than the tandem mill, and a slight possibility of better gage control. The labor cost for the single stand reversing mill is somewhat high, because such a mill is limited in capacity.

The Steckel mill shown in Fig. 6, although relatively inexpensive, has a high initial cost per ton of output. The Steckel mill is like the single stand reversing mill, in that it is flexible as to number of passes, and that it occupies a small amount of floor space. The Steckel mill has been classified as a device for rolling only the lightest gages of mild steel. However, this mill is also a useful tool in the rolling of tough stainless steels, high carbon steels, and razor-blade stock, regardless of finishing gage. The Steckel mill may be classed as a production unit, if by the use of such a mill two or more intermediate anneals may be eliminated. The capacity of the Steckel mill is approximately one-third that of the tandem mill and about one-half that of the

Fig. 5—Single Stand Reversing Mill.



single stand reversing mill. There is also a high scrap loss because of the end scrap on both ends of each coil.

The cold sheet mill, such as the installation at the Ashland Works of the American Rolling Mill Co., a photograph of which is shown in Fig. 7, was installed to utilize breakdowns where coiled strip was not available. The output of such a mill may exceed 50 tons per hour in the wider widths. The difficulties encountered with the use of such a mill are lack of flatness in the product and low economy on account of end scrap on each sheet.

There are many other advantages and disadvantages associated with each of these mills. There are also other types of special mills, such as the ring mill and Sendzimir mill, which may or may not have practical applications.

### Effects of Cold Reduction on Cold Rolled Structures and Properties and on Annealed Structures and Properties After Box Annealing

In Fig. 8a is shown the various degrees of distortion of the microstructure accompanying cold reductions from 0 to 60 per cent, and in Fig. 9, taken from a paper by R. L. Kenyon and R. S. Burns,[5] are shown the effects of various percentages of cold reduction on the shape of the stress-strain curves for cold-rolled material. In Fig. 10 is shown the relation between Rockwell hardness and the amount of cold reduction for the same samples shown in Fig. 8. In Fig. 8b are shown the various grain structures obtained after box annealing these same cold-rolled materials at 1100 degrees Fahr. In Fig. 11 (above) are shown stress-strain curves corresponding to various amounts of cold reduction after box annealing at 1100 degrees Fahr.

In Fig. 8c are shown the microstructures of material cold reduced various amounts and box annealed at 1350 degrees Fahr.

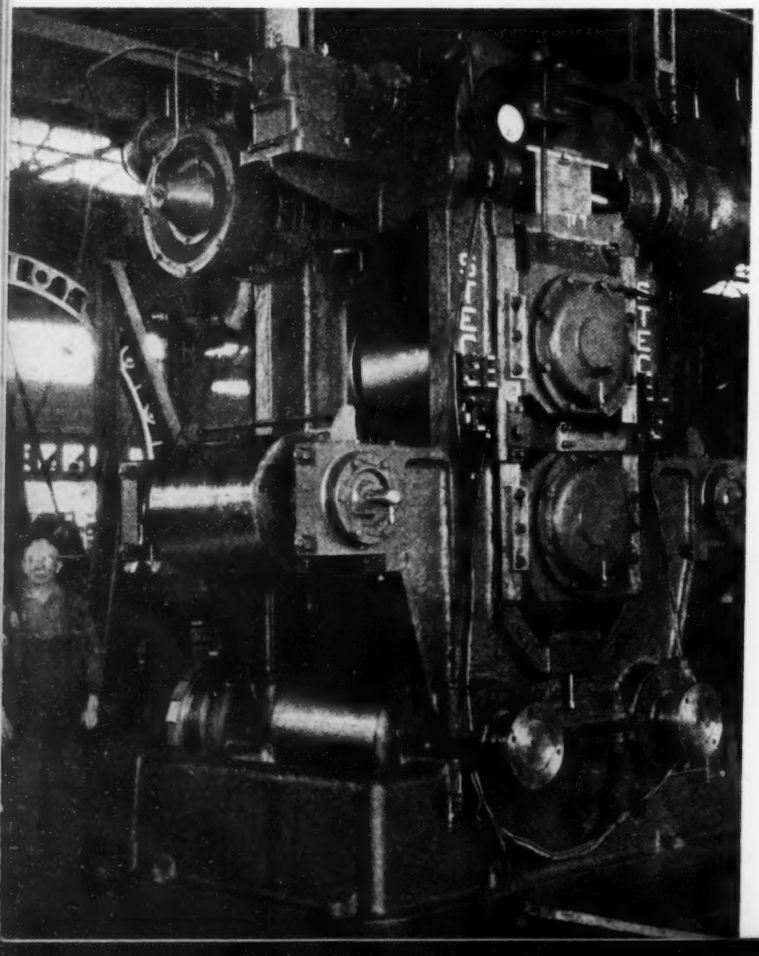
In Fig. 11 (below) are shown stress-strain curves for various cold reductions after box annealing at 1350 degrees Fahr. Fig. 12 includes graphs of variation in Rockwell hardness, yield point, tensile strength, per cent elongation in 2 inches, and yield point elongation after box annealing as affected by various percentages of cold reduction.

Some of the more important effects of various percentages of cold rolling and of box annealing temperatures on the material after box annealing are as follows:

1. There is a degree of strain which is critical in its effect on grain size and physical properties for each box annealing temperature. The results of this critical strain, with that of the box annealing temperature, are to produce large grain size with low yield point, low Rockwell hardness, low tensile strength, and lower elongation.
2. Beyond the critical strain region, the grain size is reduced as the percentage of cold reduction increases for a given box annealing temperature. This decrease in grain size is accompanied by increase in yield point, increase in yield point elongation, increase in tensile strength, and increase in total elongation.
3. For the 1100 degrees Fahr. anneal, Rockwell hardness, yield point, and tensile strength have a tendency to increase with percentage of cold reduction, up to the critical strain region. At 1350 degrees Fahr. this effect is not pronounced but seems to be present.

Fig. 12 shows the effects of box annealing on Rockwell hardness, yield point, tensile strength, elongation in 2 inches, and yield point elongation, after annealing, and needs no further discussion.

Fig. 6—Steckel Mill.



## FINISHING

In the broad outline for this symposium, Section 4-d is concerned with Cold Straightening. It involves some of the processes and their metallurgical effects, which generally are included in a group of operations called "Finishing." These processes involve temper rolling, roller leveling, and stretcher leveling.

One of the most fundamental sources of information which is broadly applicable to the metallurgical and flattening effects obtained from stretcher leveling and from so-called temper rolling and roller leveling, is the stress-strain, or the load deformation diagram obtained from tensile testing.

For discussion, a diagram of this kind is shown in Fig. 13, as obtained from fully-annealed material. It can be divided into the following portions:

5 "Autographic Stress-Strain Curves," Transactions, American Society for Steel Treating (1932).

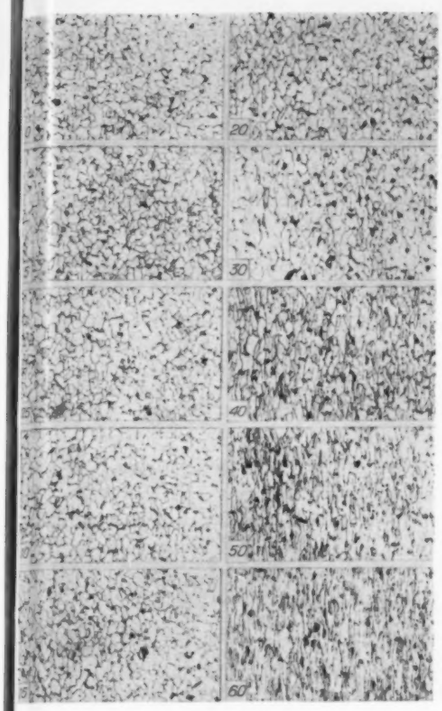


Fig. 8a—Microstructure of Mild Steel Normalized and Cold Reduced Various Amounts. Etched in 3% Nital. × 100.

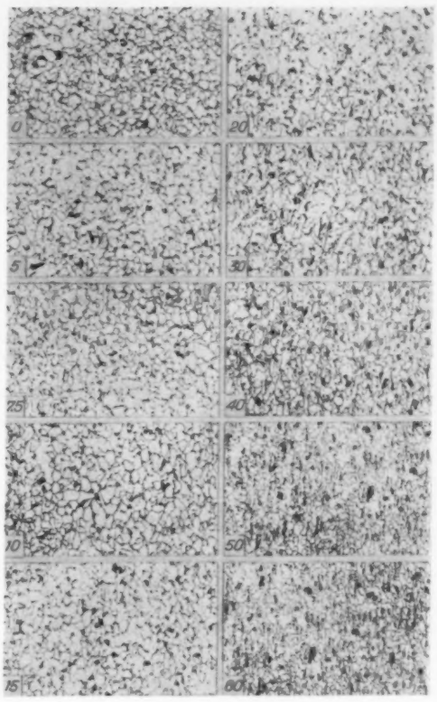


Fig. 8b—Microstructure of Mild Steel Cold Reduced Various Amounts and Box Annealed 4 Hours at 1100 Degrees Fahr. and Cooled 25 Degrees Fahr. per Hour. Etched in 3% Nital. × 100.

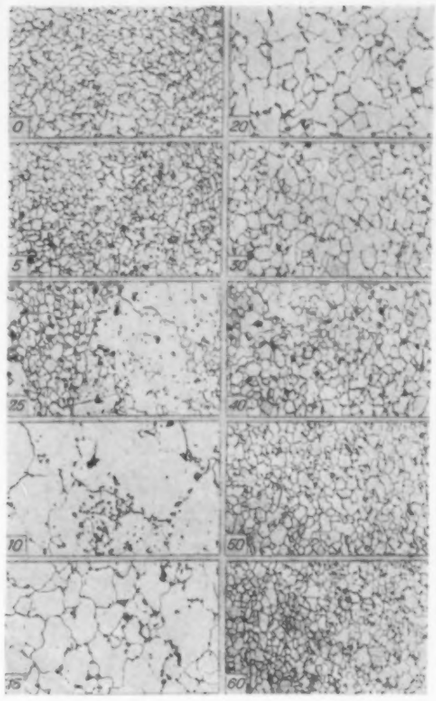


Fig. 8c—Microstructure of Mild Steel Cold Reduced Various Amounts and Box Annealed 4 Hours at 1350 Degrees Fahr. and Cooled 25 Degrees Fahr. per Hour. Etched in 3% Nital. × 100.

1. Elastic deformation.
2. Yield point elongation.
3. General elongation.
4. Localized reduction of area.

The amount of elastic deformation up to the yield point for dead-soft mild steel sheets, is of the order of 0.1 per cent. In the process of flattening by stretching beyond the yield point, variations in the elastic recovery after release of load are the major causes for failure to obtain flatness. As will be readily appreciated, the variation in elastic recovery after releasing the loading in stretching ,is due to the variation in unit stress existing in different parts of the stock subjected to the flattening process by stretching.

A more complete discussion of the relation of elastic behavior to the success of the flattening process by stretcher leveling, will be given in connection with the more detailed discussion of leveling equipment and its use.

Division 2 (Fig. 13) of the stress-strain diagram is designated as the yield point elongation region. It constitutes the wavy portion of the diagram immediately following elastic deformation. The yield point elongation portion of the stress-strain diagram is one of great practical importance, both in forming operations and operations used in flattening. It is also of very great metallurgical interest due to the considerable obscurity of the mechanism by which it results.

The following viewpoint makes possible a certain degree of understanding of the cause for this portion of the curve. In the stretching of a tensile test bar of sheet material within the plastic deformation region, there are two opposing forces in action: One is that of strengthening of the material due to work hardening; and the other that of decreased strength caused by reduction of area for those portions being plastically deformed. If the rise in stress necessary to continue elongation for any portion of the test piece which is yielding for a sample of constant cross section is greater than the reduction of stress due to the weakening effect,

Fig. 7—Tandem Mill for Cold Reducing Sheets at the Ashland Works of The American Rolling Mill Company.

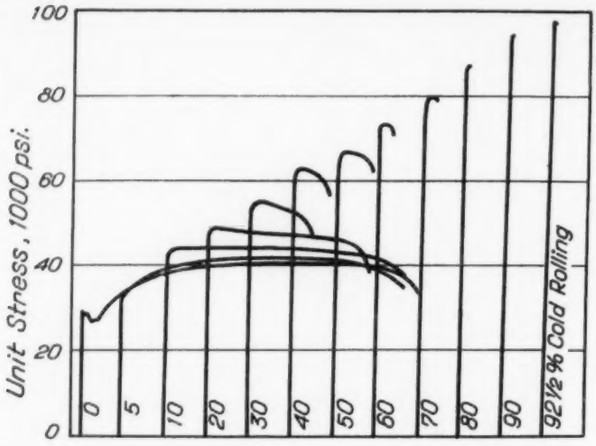



Fig. 9—Effect of Cold Reduction on the Shape of the Stress-Strain Curve of Mild Steel Sheets.

then generalized elongation will result. This is the relation between these two effects which exists in portion 3 of the diagram. If, however, the total weakening effect due to the reduction of area up to any given percentage of elongation is greater than the total rise in stress due to the work strengthening effect, then localized deformation results.

If the relation just mentioned continues long enough, the bar will pull in two at the first point at which deformation occurs. This is what happens in pulling tensile test bars of lead.

In mild steel, the piece does not pull in two at the point of first plastic deformation. Reduction of area at such a point proceeds to a certain amount, usually from 3 to 7 per cent, at which time plastic deformation starts at other points.

In actual testing of dead-soft mild steel test bars, usually the first plastic deformation occurs near the shoulders—after which deformation progresses from these two points toward the middle section of the test bar. The reason for the initiation of deformation at these places is that stress concentration occurs here, because of the rather sharp variation in width of section. The reason for the continuous progress of plastic deformation from the region near the shoulders toward the center is that concentration of stresses occurs at these points where rather abrupt changes in thickness of section has taken place.

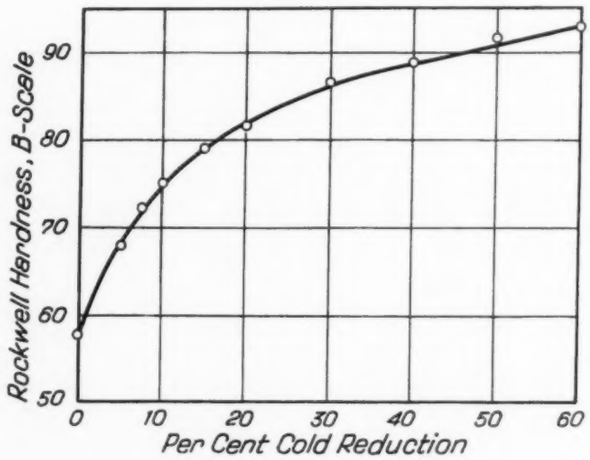
It is obvious that if localized deformation has reduced by, say 6 per cent, the cross sectional area of the test piece at one point, a very considerable amount of work strengthening must occur in this reduced section if the stress value rises high enough to start plastic deformation in the unchanged area. This behavior has some important consequences:

1. If elongation by tension is stopped before all portions of the metal are reduced enough, inequalities in thickness of section and in surface level remain. This condition is usually known by stamping producers as stretcher strains or "worms."
2. In the process of making a stamping, a wide range of elongation exists for different portions of the stamping. Consequently, stretcher straining occurs if any considerable elongation at the yield point is present as the steel goes into the press.
3. If the piece is elongated by an amount equal to, or greater than, the yield point elongation, all parts of the test section are essentially equal and the surface has to a considerable extent returned to a smooth condition. Stretching through the yield point elongation region is usually known as "pulling through the stretcher strains."
4. In the manufacture of stampings, steel sheets or strip must have the yield point elongation removed if satisfactory surface is to be obtained.
5. Strain aging may cause yield point elongation to recur after tempering.

In commercial cold-rolled steel fully annealed, the yield point elongation may range from about 3 per cent up to as much as 50 per cent of the total elongation. Usually in sheets or strip of acceptable drawing properties untreated for stretcher strain, the yield point elongation will be within the range of from about 3-7 per cent. Some of the factors with which yield point elongation is related are:

Yield point elongation is related to elastic ratio, $\frac{\text{yield point}}{\text{tensile strength}}$. The lower the elastic ratio, the less the yield point elongation.

Fig. 10—Effect of Cold Reduction on the Rockwell "B" Hardness of Mild Steel Sheets.



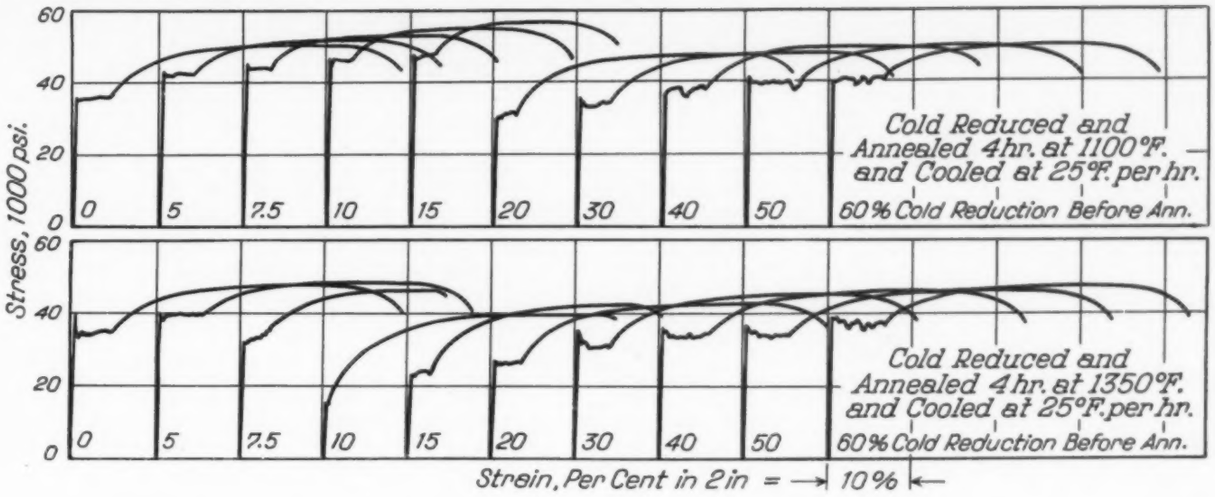



Fig. 11—Effect of the Amount of Cold Reduction Before Annealing on the Shape of the Stress-Strain Curve for Mild Steel After Box Annealing at 1100 and 1350 Degrees Fahr.

Elongation at the yield point is usually greater on fine-grained material than on coarser grained material. (See Figs. 8 and 11.)

In Fig. 12 is shown the variation in yield point elongation with various percentages of cold reduction before box annealing at two different temperatures. The variation in yield point elongation, as shown in this figure, is related to variation in grain size, which in turn depends on the amounts of cold reduction used before annealing.

Consideration of the plastic deforming stresses as affected by work strengthening on one hand, and by reduction of cross sectional area on the other, as already stated, indicates that elongation at the yield point is due to a low rate of work strengthening during early stages of plastic deformation. Among a number of scientific workers, there is the view that two different types of structural changes are in progress during plastic deformation, one which has been termed "Fragmentation," and the other "Deformation by Slip." According to this view, one may assume that fragmentation, so far as it affects the breaking-up of some structure, might constitute a weakening effect, or at least it might result in a low rate of work strengthening.

The work strengthening effect of slip plane deformation may be due to the bending of planes of easiest slip, together with the development of preferred orientation. Part of the strengthening effect of the development of preferred orientation no doubt is due to planes of slip

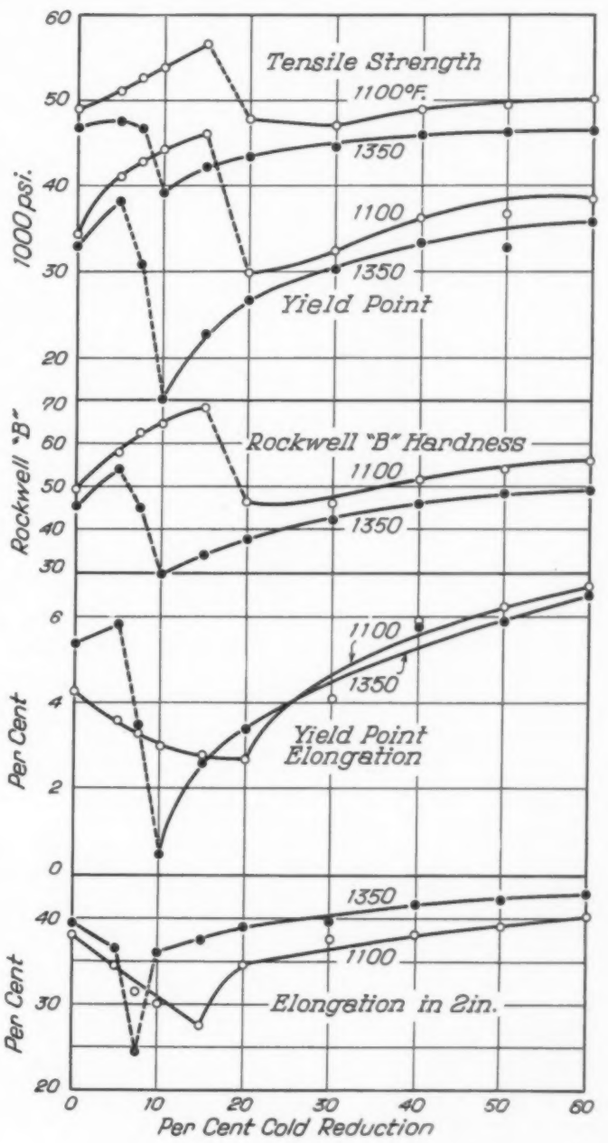



Fig. 12—Tensile Properties of Mild Steel Sheets Cold Reduced Various Amounts and Box Annealed at 1100 and 1350 Degrees Fahr.

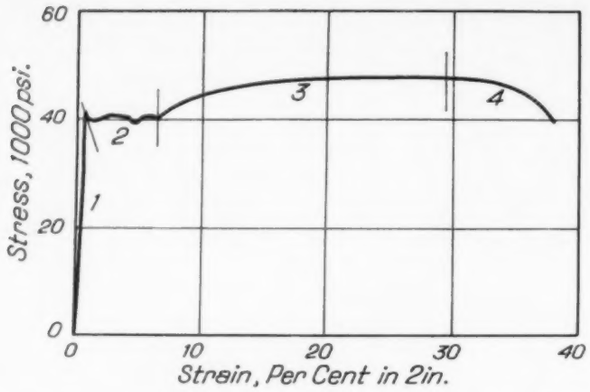



Fig. 13—Typical Stress-Strain Diagram of a Dead-Soft Steel Sheet.

taking positions with respect to the distorting forces, which offer greater resistance to further deformation. If the fragmenting process is more predominant during initial stages of deformation than is the development of orientation, lower rates of work strengthening may result.

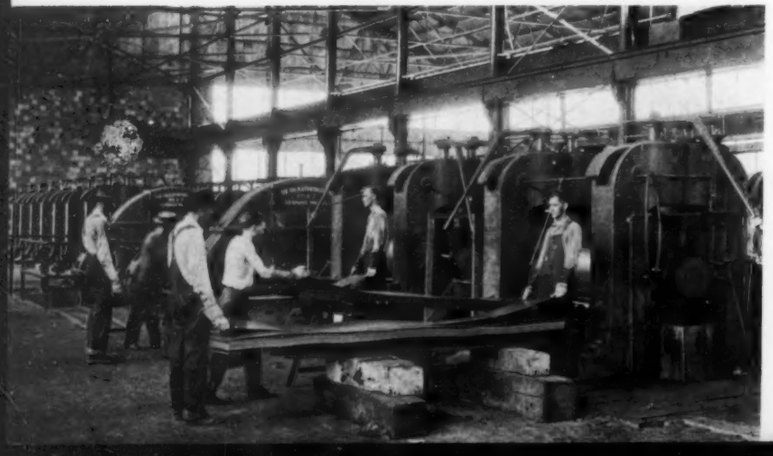
True stress curves show a continuous rise in the stress with deformation, even for metals which show elongation at the yield point. This indicates that the work strengthening process is in operation throughout the entire plastic deforming process.

Proceeding with the discussion of the two remaining portions of the stress-strain diagram, it may be said that the smooth stress rising portion of this curve is obtained when the rate of work strengthening is greater than of weakening. The fourth portion of this curve is characterized by a reduction in load as elongation proceeds. It may be accounted for by the fact that the rate of work strengthening has fallen to values that are too low to make up for the weakening effect caused by reduction in cross section. This rapid action of necking-down at one point just precedes failure.

## ELIMINATION OF YIELD POINT ELONGATION (PREVENTING STRETCHER STRAINING)

The method used to prevent stretcher strain consists of subjecting the material to small cold reductions (from 0.5 to 2 per cent) by rolling on a "temper mill." In Fig. 14 is shown a photograph of a series of temper mills. The elimination of stretcher strain by this method consists in effecting reduction by sufficient cold rolling to eliminate the yield point elongation.

Fig. 14—Temper Rolling Mills.



The relation between the yield point elongation and the amount of temper rolling required are shown in Fig. 15. The following are the more important facts in regard to effects of types of temper mills and metallurgical characteristics of stock on the amount of temper rolling necessary to eliminate strain:

1. The smaller the grain size of the steel, the greater the yield point elongation; and, the greater the amount of temper rolling necessary.
2. Sheets with polished or smooth surface with the same yield point elongation, require more temper rolling than do sheets with dull surfaces.
3. The smaller the rolls for tempering, the smaller the amount of reduction necessary. (See Fig. 16.).

## FLATTENING OR LEVELING

Fig. 17 shows three roller levelers. The roller levelers commonly in use have a number of top and bottom rolls. The upper and lower rolls are staggered so that in passing through the leveler ,the sheets are flexed alternately up and down. This has the effect of cold working the surfaces more than the interior of the sheet. With levelers of the proper amounts of staggering of rolls, flatness may be obtained with essentially no increase in length of the sheet.

At the entrance side of the leveler, the axes of top and bottom rolls are closer together than at the exit side. This results in a heavier flexing in passing through the earlier rolls of the machine. At the exit side the action is chiefly that of straightening. Prior to leveling, it is the usual practice to run the material through a temper mill to remove most of the yield point elongation. Unless this is done, breaks in the stock occur near the entrance side of the leveler.

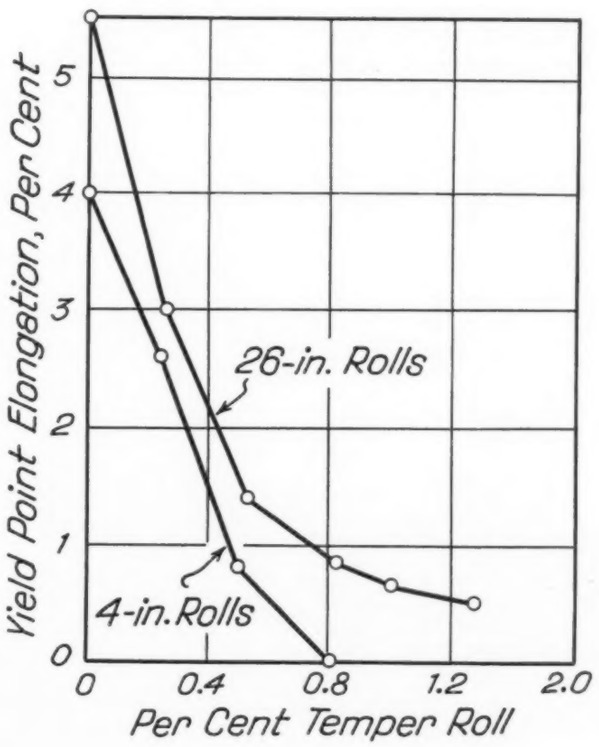
A photograph of a stretcher leveler is shown in Fig. 18. This method of flattening is resorted to when extreme requirements in flatness must be met. As in the case of the roller leveler, it is necessary to have treated the stock by temper rolling before subjecting the material to the stretcher leveling operation.

There are some interesting facts which are worthy of mention in connection with the elimination of strain by cold rolling on the one hand, and by stretching on the other. Application of the analysis already given of the stress-strain diagram indicates that stretching must be carried to a point which takes up all of the elongation at the yield point, if stretcher straining is to be avoided. This would mean that stretcher leveling must be carried through elongations from about 3 per cent, as a minimum, to some 8 per cent. It should be stated that stretcher leveling is never used to eliminate strain; it is only used to obtain flatness. If a material

which shows, for example, 4 per cent elongation at the yield point in the tensile test is elongated by cold rolling as little as 0.80 per cent, all of the elongation at the yield point will have disappeared. In accordance with what has already been stated, tensional stretching of this same material must have been carried to at least 4 per cent in order to have eliminated yield point elongation. This wide difference in values by cold rolling and tension is due to the fact that in the tempered material it is not necessary for the work strengthening process to make up the weakening effect of the reduction of section, which would have resulted in case yield point elongation were removed by stretching only. Stated in another way: It is only necessary to plastically deform the material by cold rolling to a point where the rate of work strengthening has risen to a value greater than that of weakening, due to reduction in cross section. The failure to obtain stretcher strains in low percentages of cold rolling is due to the fact that in the cold rolling operation, all parts of the material are reduced to the same cross sectional area as they pass through the rolls.

Experience shows that there are certain other requirements in sheet and strip products as they come to the stretcher leveling operation if flatness is to be obtained. In general, only certain types of nonflatness can be corrected by stretcher leveling. Some materials which are distinctly more out-of-flat than others, can be flattened satisfactorily by stretching.

Fig. 15—The Effect of the Amount of Yield Point Elongation as Annealed on the Amount of Temper Rolling Necessary to Eliminate the Yield Point Elongation. Temper Rolling Done with 4-Inch Diameter Rolls.



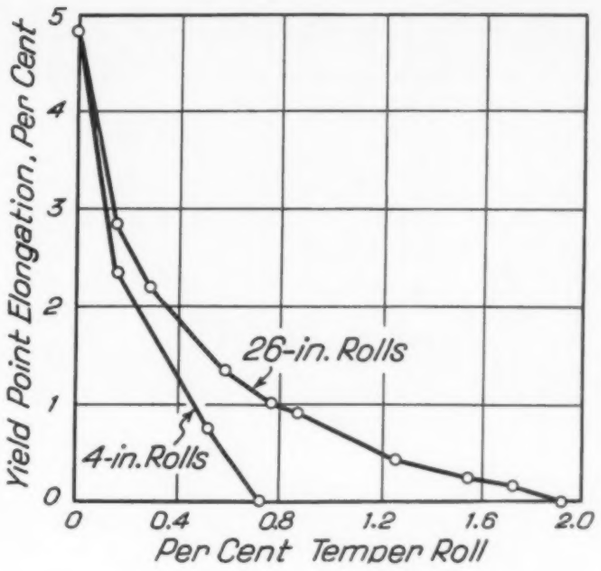




Fig. 16—The Effect of Roll Diameter on the Amount of Temper Rolling Necessary to Remove the Yield Point Elongation.

A few typical cases will be mentioned:

1. Material which has a variation in physical properties across the sheet usually does not stretcher level satisfactorily. The difference in physical properties at various points across the sheet produces changing values for unit tension if the grips on the leveler hold perfectly. These differences in unit stress produce variation in strain, within the elastic range, across the sheet, with the result that release of the load produces different amounts of elastic contraction which causes nonflatness.

2. Nonuniformity in gage across a sheet of material whose physical properties are uniform in this direction, frequently gives trouble in stretcher leveling due to difficulties in obtaining perfect gripping. Slippage in the grips will produce different unit stresses in different parts of the sheet. If this slippage is high enough so that stretching is not carried deffnitely beyond the yield point in all parts of the material, varying amounts of elastic contraction will result upon release of load, which in turn produces nonflatness.

   Then, too slippage causes different amounts of elongation in various parts of the sheet. This produces unsatisfactory flatness.

   Great improvements in stretcher levelers have been made in the last few years. Instead of building the grips all in one rigid piece, they are made in short sections. This construction makes possible a more satisfactory adaptation of grips to slight variations in gage.

3. As the physical properties of sheet material rise, the leveling operation becomes more diffi-

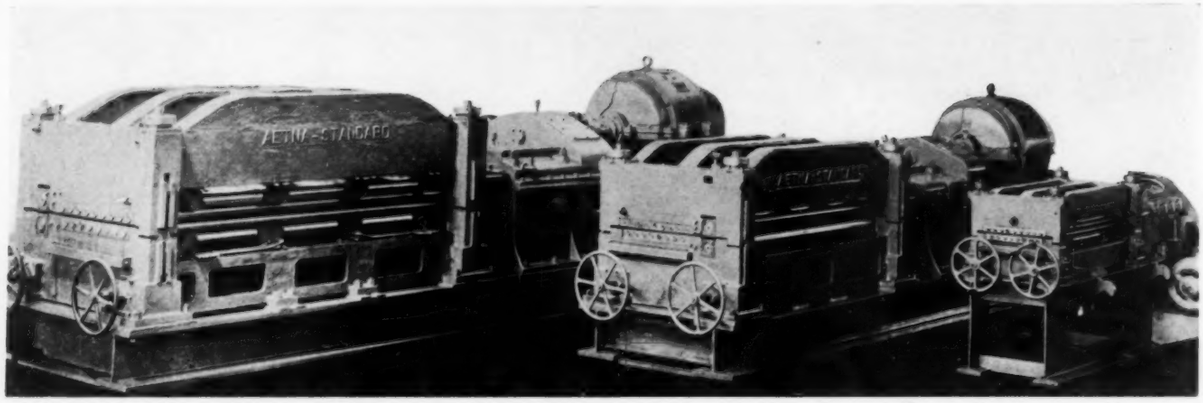


Fig. 17—Roller Levelers.

cult because of the greater elastic contraction upon release of load, as well as greater difficulties in obtaining perfect gripping in the leveler.

Experienced operators of stretcher levelers have come to recognize certain conditions of nonflatness and of physical properties which can, or cannot, be successfully leveled. When shapes of stock, physical properties, and various degrees of nonflatness are considered, it is easy to appreciate how very complex problems in stretcher leveling may arise.

The discussion of many of these special features is beyond the scope of the present paper.

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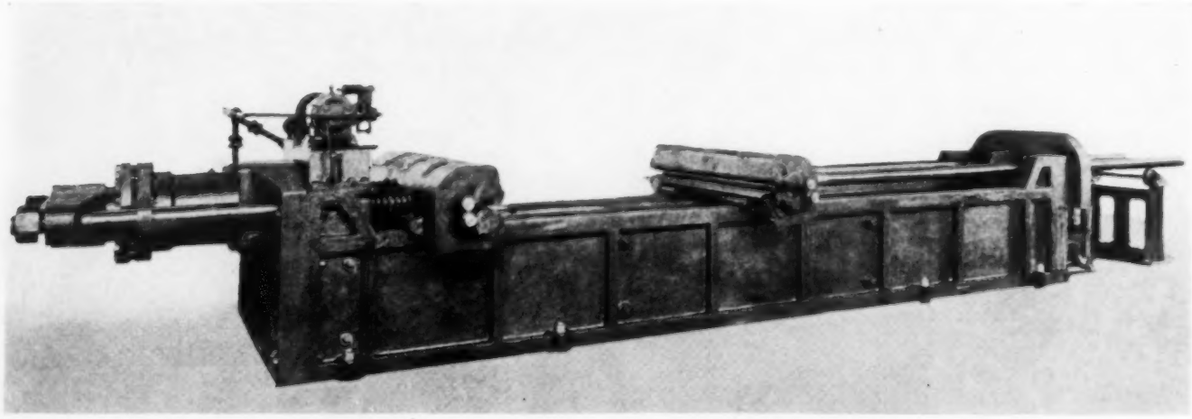
Fig. 18—A Stretcher Leveler.



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*Lubrication, Its Importance in Mill Equipment—Designing for*—By Chas. R. Hand, March 1936, 13.

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# Items of Interest

**Harry H. Holloway,** general superintendent of the Monroe, Mich., plant of the Newton Steel Co., subsidiary of Republic Steel Corp., Cleveland, has been appointed assistant manager of the Cleveland district of Republic. Mr. Holloway began his career with the former American Sheet & Tin Plate Co. in 1909, and during the past 27 years has been associated with the LaBelle Iron Works, Steubenville, O.; Deforest Sheet & Tin Plate Co., Niles, O.; Brier Hill Steel Co., Youngstown, O., in charge of the company's sheet mill at Niles; Sharon Steel Hoop Co., in production and sales departments; and Apollo Steel Co., Apollo, Pa., as assistant to the president. He joined Newton in 1935.

**Robert Ritze** has been placed in charge of the Monroe, Mich., plant of Newton.

**John W. Hughes** has been transferred from the Warren, O., plant to Cleveland where he will take charge of Republic's new $15,000,000 strip mill. Mr. Hughes became associated with the Warren plant in 1913; in 1929 he was made superintendent of the hot strip finishing department, and during the past four years he has been superintendent of all the hot strip departments.

**Raymond C. Gintert,** assistant superintendent of the Warren hot strip department, has been appointed superintendent to succeed Mr. Hughes. Mr. Gintert spent three years teaching school before entering the engineering department of the Truscon Steel Co., Youngstown. From there he went to the Trumbull Steel Co. in 1917, spending a year in the sheet department. The balance of the 19 years with Trumbull, which later became a part of Republic, was spent in the hot strip department.

**James J. Bowden,** formerly assistant superintendent of sheet and tin department, Warren district, has been transferred to Cleveland where he will act as chief metallurgist. Following graduation from Ohio State university in 1914 as a mining engineer, he spent the next two years in Calcutta, India, for the Standard Oil Co. of New York. In 1917 he became identified with the Colonial Steel Co., Pittsburgh, as metallurgist; following air service during the World War he became metallurgist for the Laclede Steel Co. Later he joined the sales department of Wheeling Steel Corp., and after a short time left to resume his position with Laclede as chief metallurgist. In 1928 he joined American Rolling Mill Co., and in the same year joined Republic as chief metallurgist for the Warren district.

**Bert Kennedy** has been appointed assistant chief metallurgist.

**B. R. Richardson,** former superintendent, Enduro sheet and strip divisions of Republic, has been made superintendent of United Steel division, Canton, O. He became identified with the former American Sheet & Tin Plate Co., at Gary, Ind., in 1919 and since then has been associated with the Indiana Rolling Mill Co., Mansfield Sheet & Tin Plate Co., Central Steel Co. at Massillon, now a part of Republic, and the South division of United Alloy Steel Co. He was made superintendent of the Enduro sheet and strip divisions in 1935.

**James G. Davey:** superintendent, Canton Tin Plate Co., a Republic subsidiary, succeeds Mr. Richardson as superintendent of the Enduro sheet and strip divisions.

Howard B. Carpenter, manager of the Republic Steel Corporation, Cleveland district, (seated right) discusses details of the corporation's $15,000,000 44″ blooming mill and 98″ continuous hot and cold strip mill project with (standing, left to right) James J. Bowden, new chief metallurgist for the district; Harry H. Holloway, newly appointed assistant district manager; J. H. Van Campen, chief district engineer, and John W. Hughes (seated left), who will be in charge of the new mill.

JOHN L. YOUNG

EDWARD J. HANLEY

F. R. FISHBACK

**John L. Young** has been made manager of machinery sales for United Engineering & Foundry Company. Mr. Young joined United on February 1 of this year and has been associated with the sales department as service engineer. Previous to joining United, he was associated with the Timken Roller Bearing Company of Canton, Ohio, for fourteen years, having joined that company in 1921 to specialize in the application of Timken bearings for mine cars. This brought Mr. Young to the Pittsburgh district where he served for a number of years as district manager and for the year preceding his transfer to United, he was assistant general manager of the industrial division located at Canton, Ohio.

Mr. Young was graduated from The University of Indiana in 1921 with a degree of Bachelor of Science. During the number of years that Mr. Young spent with the Timken Roller Bearing Company in Pittsburgh, he specialized in the application of roller bearings to steel mill equipment and through that connection became well acquainted with the development of rolling mill machinery and the various rolling mill organizations.

**Joseph Kinney** has been made assistant manager of machinery sales for United Engineering & Foundry Company. Mr. Kinney joined United in 1931 and has been associated with the machinery sales division since that time. He was in the class of 1926 at Dartmouth College and previous to joining United was associated with industrial sales and manufacturing companies.

▲

**Edward J. Hanley** has been appointed secretary of the Allegheny Steel Company, succeeding Frank H. Stephens, who has resigned from the post but continues as a vice president and treasurer of the company. Mr. Stephens has been connected with the company since its organization in 1901.

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**H. W. Schmid** of 1955 Ruckle Street, Indianapolis, Indiana, has been appointed to represent The Ohio Electric Manufacturing Company of Cleveland, Ohio, for the sale of Ohio Motors in Indianapolis territory.

▲

**F. R. Fishback,** president of the Electric Controller & Manufacturing Company, Cleveland, Ohio, has been elected president of the National Electrical Manufacturers Association to succeed F. C. Jones of the Okonite Company, who has been president of the National Electrical Manufacturers Association for the past two terms.

Mr. Fishback has long been active in the affairs of this society as a member of the executive committee and board of governors.

▲

**William E. Umstattd** was elected president of The Timken Steel & Tube Company which is a wholly-owned subsidiary of The Timken Roller Bearing Company, in addition to continuing his present capacity as President of the parent company.

**H. H. Timken, Jr.,** previously a vice-president of The Timken Steel & Tube Company, was made executive vice-president of The Timken Steel & Tube Company, in addition to his present capacity as vice-president and director of The Timken Roller Bearing Company.

**W. Robert Timken** was elected director of The Timken Roller Bearing Company and of The Timken Steel & Tube Company to fill the vacancy of the unexpired term.

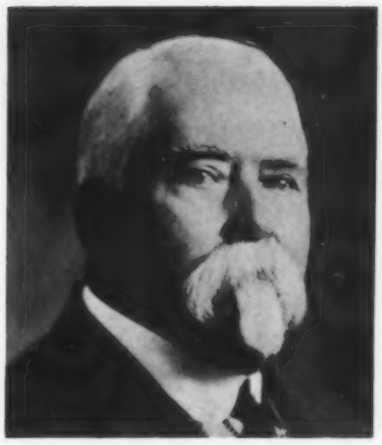
**John E. Fick** was appointed general superintendent of the steel and tube mills.

**Frederick J. Griffiths** resigned as director of The Timken Roller Bearing Company and president and director of The Timken Steel & Tube Company.

**K. B. Bowman** resigned as general superintendent of the steel and tube mills of The Timken Roller Bearing Company.

J. R. PATTERSON

M. J. VAN LEEUWEN



WILLIS LARIMER KING

**J. R. Patterson,** formerly general manager of sales, has been made vice president in charge of sales for the Mackintosh-Hemphill Company, Pittsburgh. F. C. T. Daniels, identified with the company for a number of years in engineering capacities, has been named vice president in charge of research and development. C. Howard Paul, assistant treasurer, has been named assistant to the president. Mr. Paul retains his former position of assistant treasurer.

▲

**M. J. van Leeuwen,** who, until recently, was in charge of the Chicago office of the electric industrial truck division of the Yale and Towne Manufacturing Company, has joined the sales department of the Bull Dog Electric Products Company of Detroit, Michigan and will be associated with their Chicago office in the sale of their products in the Chicago district.

Mr. van Leeuwen was born in Passaic, N. J., on December 20th, 1899. He was educated in the public schools of Massachusetts and at the United States Naval Academy at Annapolis, Maryland, and served in the United States Navy during the World War.

In 1923 he became associated with the Condit Electrical Manufacturing Company of South Boston, Massachusetts as a sales engineer in their New York office. This position he held until 1925 and resigned to take over the duties of sales manager of the Rowan Controller Company of Baltimore, Maryland.

In 1927 Mr. van Leeuwen came to Chicago and established himself as a manufacturer's agent. He represented the Rowan Controller Company of Baltimore, Maryland and the Nichols-Lintern Company of Cleveland, Ohio for over six years.

▲

## *Died*

**Willis Larimer King,** a Director of the Jones & Laughlin Steel Corporation died Friday, December 11, 1936, after a short illness. For sixty seven of his 86 years, Mr. King has been identified with J & L, having started with them in 1869. For many years he was one of the outstanding leaders in the iron and steel industry.

Entering the industry four years after the close of the Civil War, Mr. King saw the great age of iron give way to the still greater age of steel, and saw the production of Jones & Laughlin increase from 100 tons of iron per day to approximately 10,000 tons of steel ingots daily.

When Mr. King, at the age of 18, began as a clerk in the Jones & Laughlin order department, there were only five people in the general office. He advanced through various positions, principally in the selling end of the business, and in 1899 was elected secretary and a member of the board of managers of Jones & Laughlins, Limited, and one year later was elected Vice Chairman.

He was active in forming the Jones & Laughlin Steel Company in 1902, which superseded Jones & Laughlins, Limited, and was elected a Director, Vice President, and a member of the Executive Committee of the Company. In 1922, with the formation of the Jones & Laughlin Steel Corporation, he was elected to fill these same positions which he held until 1934 when he retired as Vice President and member of the Executive Committee, but retained his directorship.

Known for many years as the "dean of the steel industry", Mr. King was active in the formation of the American Iron & Steel Institute in 1908, and was one of its directors until 1928. During most of that period he was also Vice-President of the Institute, and since 1928, has been honorary Vice-President. He was awarded the Gary Medal in 1933 by the American Iron & Steel Institute, which annually awards the medal for outstanding achievement in the iron and steel industry. The award to Mr. King was for his achievements as "a leader in inspiring high ideals and promoting confidence and good will in the welfare of the iron and steel industry".

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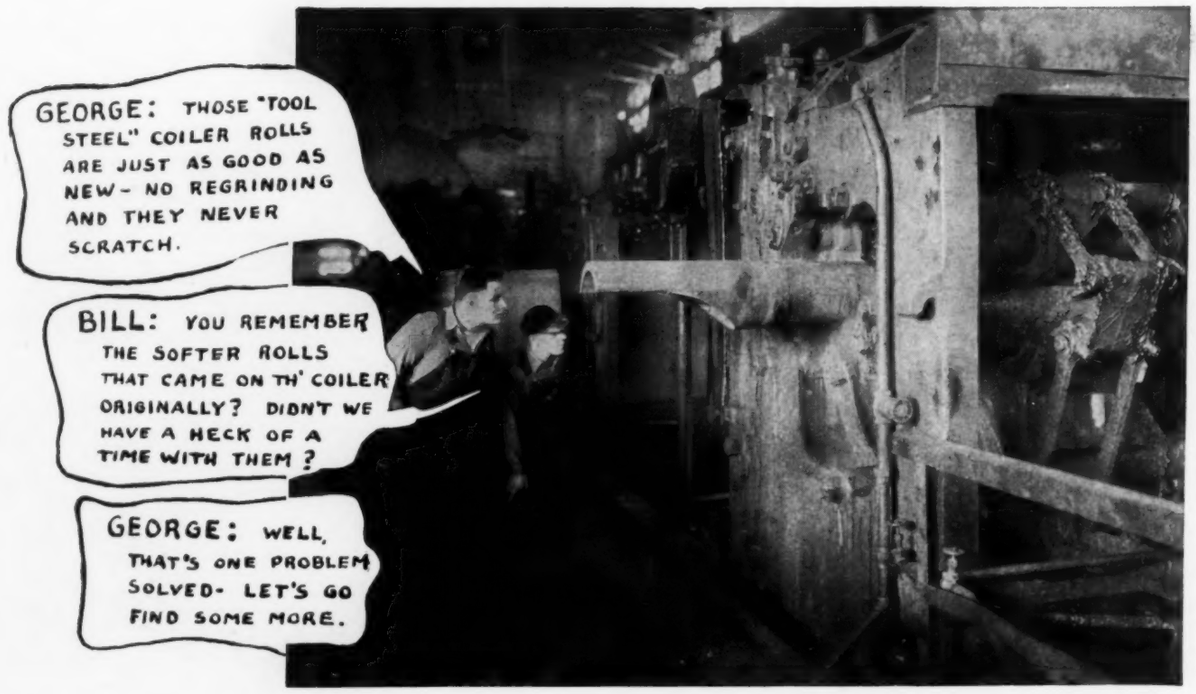
*Division of McGraw Electric Co.*


GEORGE: THOSE "TOOL STEEL" COILER ROLLS ARE JUST AS GOOD AS NEW - NO REGRINDING AND THEY NEVER SCRATCH.
BILL: YOU REMEMBER THE SOFTER ROLLS THAT CAME ON TH' COILER ORIGINALLY? DIDN'T WE HAVE A HECK OF A TIME WITH THEM?
GEORGE: WELL, THAT'S ONE PROBLEM SOLVED - LET'S GO FIND SOME MORE.

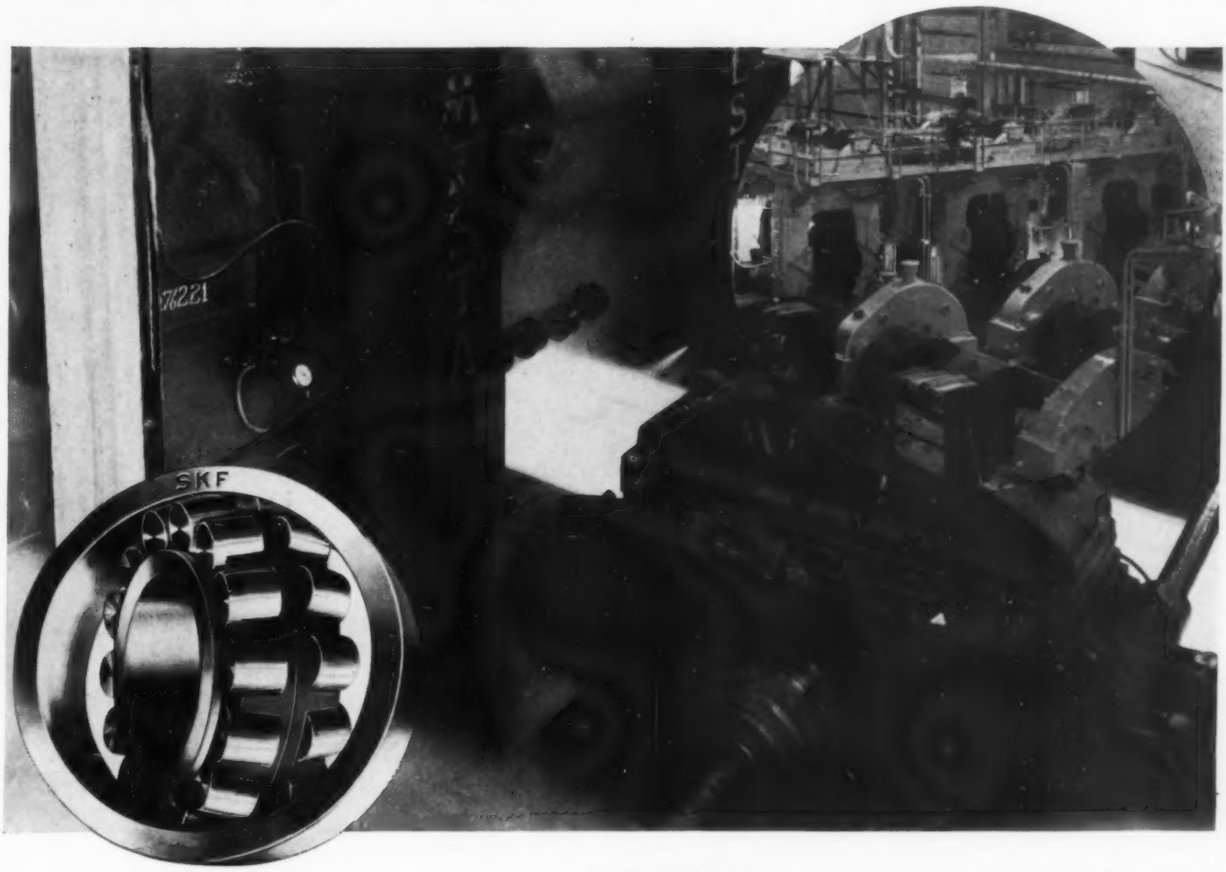
**LIKE THE BON AMI CHICK,**

"TOOL STEEL" ROLLS *"Have Never Scratched Yet"*

SKF BEARINGS ASSURE

# SIMPLICITY

## *in* DESIGN! ASSEMBLY! MAINTENANCE!




SIMPLICITY . . . that's the word that steel mill operators use when describing SKF Self-Aligning Spherical Roller Bearings. It is the answer to anti-friction problems in design, assembly and maintenance.

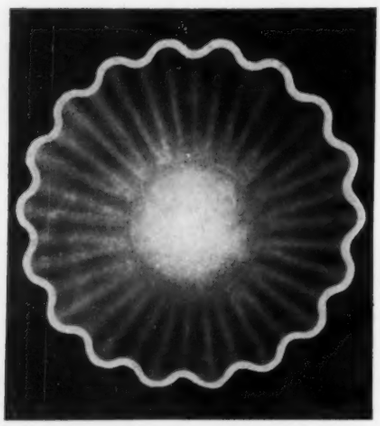
In *design* the self-aligning feature of SKF simplifies housings which need no special provisions for load distribution. In *assembly* self-contained SKF are quickly mounted and require no set-up adjustment. In *maintenance* SKF require no correction for wear. Widely used for hot and cold tandem strip mills. Send for catalog, "SKF Rolling Mill Data for Calculation and Design."

SKF INDUSTRIES, INC., Front St. & Erie Ave., Phila., Pa.

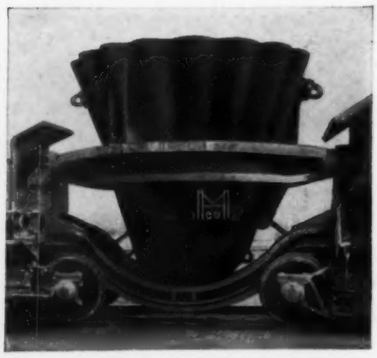
3750

SKF
ROLLER BEARINGS

Side view of a Johnston Corrugated Cinder Pot



Top view of a Corrugated Pot



Corrugated Pot in a car

# LONGER LIFE AT LESS COST

Johnston Corrugated Cinder Pots have proved that they will outlive all previous types of pots *many times.* No Johnston Cinder Pot has ever worn out and the first one has been in service three years.

The cracking and bulging so characteristic of conventional types of cinder pots are due to expansion and contraction. All previous attempts to overcome these troubles have been based on stiffening of the walls to resist the expansion. In the Corrugated Cinder Pots, the vertical corrugations permit the pot walls to expand and contract freely. This eliminates strains and ends the high maintenance and replacement costs.

This design of pot cleans itself much more readily than any plain wall pot.

Johnston Cinder Pots can be made to fit your present cinder car trunnion ring and are made in all sizes, for blast furnace and open hearth use.

Mackintosh-Hemphill Company has the exclusive license for manufacture and sale of Johnston Cinder Pots. We will be glad to show you successful installations and service records. As many as eight repeat orders have been received from a single customer.

Ask the man who uses them.

**MACKINTOSH-HEMPHILL CO.**

**PITTSBURGH AND MIDLAND, PA.**

(*Right*) This photograph shows 11 of the 16 Corrugated Cinder Pots now in service at the Weirton Steel Company plant at Weirton.

JOHNSTON
CORRUGATED
CINDER
POTS
U. S. Patent 2,057,528

# A Continuous Strip

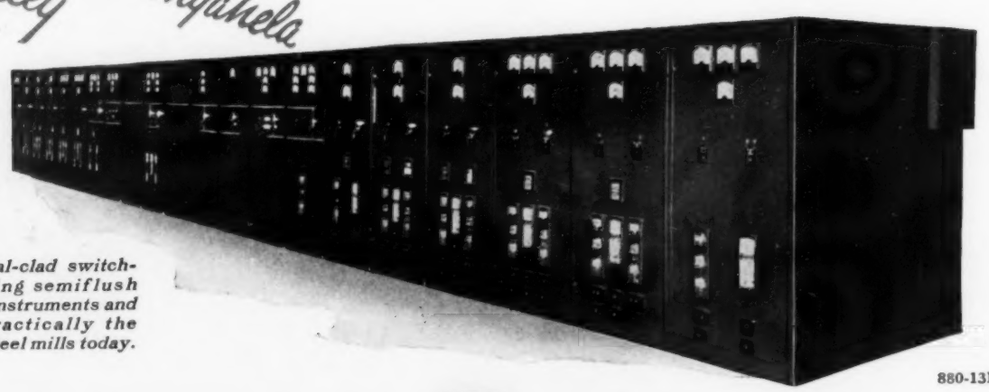
1934 A hot-strip mill in Pittsburgh
1934 A hot-strip mill in Youngstown
1934 A cold-strip mill in Youngstown
1935 A blooming mill in Pittsburgh
1935 A hot-strip mill near Buffalo
1935 A cold-strip mill in upper Ohio Valley
1935 A hot-strip mill near Detroit
1935 A cold-strip mill near Baltimore
1936 A hot-strip mill in Pittsburgh
1936 A cold-strip mill in Pittsburgh
1936 A rod mill near Chicago
1936 A semicontinuous plate mill near Pittsburgh

1936
The Latest Job—
48 units for a
large power house
in the Monongahela
Valley

*All 500,000-kva G-E metal-clad switchgear. Shipped assembled—received complete, ready to operate*

**RENEWED and conclusive evidence that General Electric metal-clad switchgear is the accepted mill standard.**

**G-E BUILDS WITH STEEL**



*Typical metal-clad switchgear, showing semiflush mounting of instruments and devices—practically the standard of steel mills today.*

880-13H

**GENERAL ELECTRIC**

# STEEL FOR STRENGTH

Squirrel-cage Reliance Induction Motor with Ball Bearings
(Type "AA", Open-slot Frames 444—585)

**STRENGTH INDEED!** An all-steel frame to start with, as essential to a motor as good, healthy bone structure to the body. Supplemented by husky bearing brackets, shafts, bearings and other "organs". Altogether, a rugged, long-lived unit of equipment that cares not how *heavy* your heavy-duty service may be. That's the Reliance Type "AA" Motor all over . . . An organization committed to lengthening motor life by incorporating every endurance feature . . . An adequate, trained force ready to hop on your job personally—and with dispatch . . . Such factors as these deserve your consideration when sources of supply are discussed.

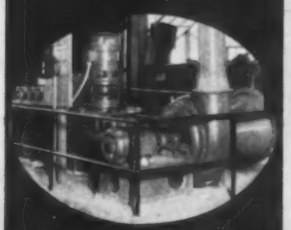
**RELIANCE ELECTRIC & ENGINEERING COMPANY**
1088 IVANHOE ROAD CLEVELAND, OHIO
**Branches: Boston, Buffalo, Chicago, Cincinnati, Detroit, Greenville, (S. C.), New York, Philadelphia, Pittsburgh.** ***Representatives in other principal cities***

# RELIANCE A-C D-C MOTORS

There's a lot of room for making connections in the conduit outlet box. Conduit can be brought in from the top, bottom or either side.

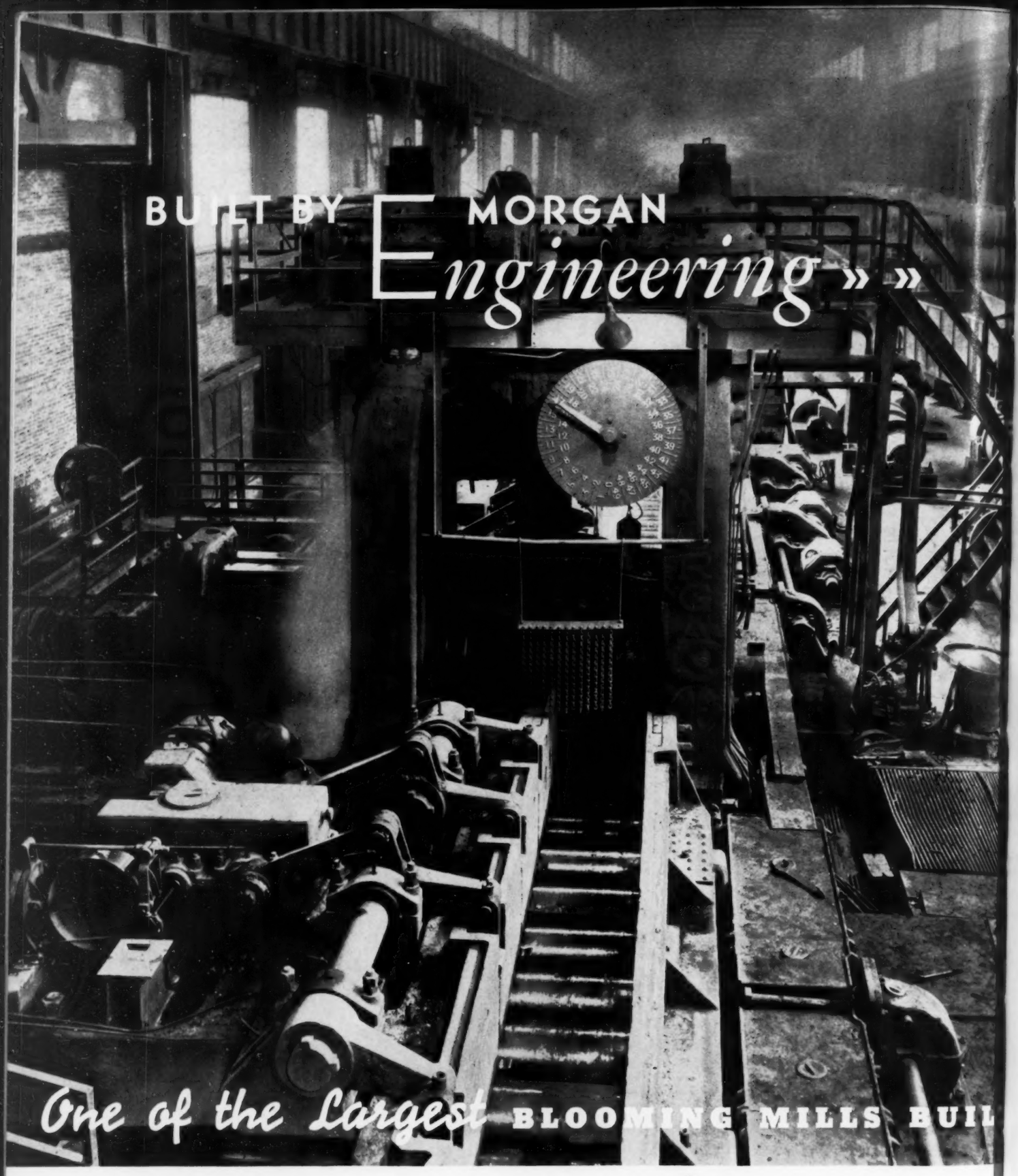
The wrenches commonly used for maintenance work will reach all bolt heads.

The bottoms of the cast-steel feet are finished and base holes are jig-drilled.



Vertical Type "AA" Motor driving Whiting Coal Pulverizer on malleable iron melting furnace. Horizontal motor on exhauster.

A 4-speed squirrel-cage motor drives pinch rolls and levellers on this Budd-McKay Sheet Processing Machine. A special-torque motor is used for quick movement of processing roll.




● Few blooming mills have been built during the past ten years, but this is one of the largest ever built and one of the newest. This 54″ blooming mill has one-piece steel castings for its housings, insuring rigidity. A two-cylinder roll balance allows for minimum headroom. Manipulator is of the over-head type, compact and accessible. Finger lifts and side-guards, each operated by two motors in series, assure quick acceleration and more tonnage. Morgan responsibility extends from design to construction and installation–assuring mill operators of satisfactory production as specified, and traditional integrity of Morgan engineering.

★

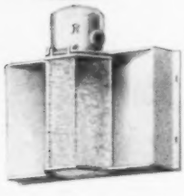
★ **DESIGNERS • MANUFACTURERS • CONTRACT**

★ BLOOMING MILLS • PLATE MILLS • STRUCTURAL
ELECTRIC TRAVELING CRANES • CHARGING MACH
★ INGOT STRIPPING MACHINES • SOAKING PIT CR
ELECTRIC WELDED FABRICATION • LADLE CRA
★ STEAM HAMMERS • STEAM HYDRAULIC FOR
PRESSES • SPECIAL MACHINERY FOR STEEL

★ **THE MORGAN ENGINEERING CO., Alliance,**
Pittsburgh, 1420 Oliver Bldg. New York, 11 W. 42nd

★

# for DEPENDABLE OUTDOOR LIGHTING specify Pyle-National *Heavy Duty Floodlight Projectors*



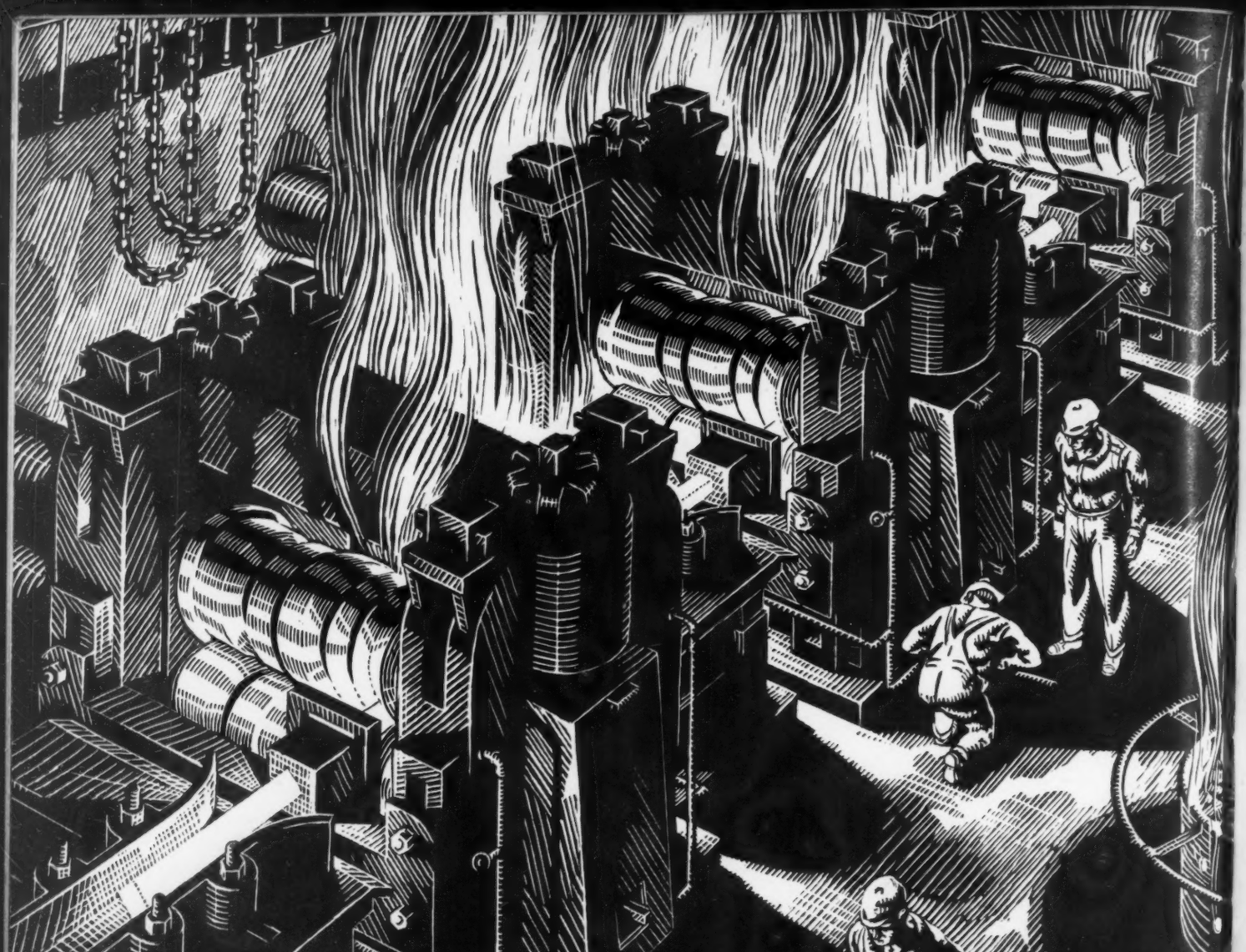
Pyle-National floodlight designs embody accurate light control and many features of construction that insure reliable lighting service even under the severest operating conditions. The cases, either in sheet or cast metal, are substantially built, and provided with simple means for rigid, accurate mounting. Cases are completely enclosed, sealing the interior and affording maximum protection to lamp bulbs and reflectors. Cleaning and other maintenance is reduced to the absolute minimum. Exclusive reflector design and the use of light control lenses provide high efficiency lighting of maximum usefulness.

The Pyle-National line includes a complete range of types and sizes, from the 150-watt Utility Floodlight to 5,000-watt projectors. Any requirements of large-area lighting, indoors or out, can be met efficiently and economically. Write for special floodlight bulletins.

## PYLE-NATIONAL

The Pyle-National Company, General Offices and Works, 1334-58 North Kostner Avenue, Chicago, Illinois • *Offices:* New York, Baltimore, Pittsburgh, St. Louis, St. Paul, San Francisco

**CONDUIT FITTINGS • LOCOMOTIVE ELECTRICAL EQUIPMENT • FLOODLIGHT PROJECTORS**



# PHOENIX ROLLS IN SERVICE

When operations are at their peak and every part of the plant is working at capacity, Phoenix Rolls are depended upon to "stand the gaff". Ask any user of Phoenix Rolls if this confidence is misplaced?

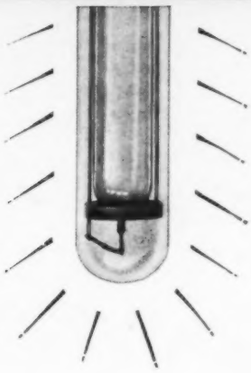
## PHOENIX ROLLS

PHOENIX STEEL, for unusual strength; PHOENIX "A" (steel alloy), for strength and wear; PHOENIX METAL—PHOENIX "K", for strength, wear and finish; PHOENIXLOY (uniformly hard), for flat rolling where high finish of extremely thin gauge of material is required to be free from all marks or defects. PHOENIX CHILL; PHOENIX NICKEL CHILL; for all flat rolling requiring finish. Also tube mill rolls of quality material best suited to the kind of service required.

## PITTSBURGH ROLLS CORPORATION

### PITTSBURGH, PA.

# FOR HIGH EFFICIENCY MERCURY LAMPS



The new mercury lamps give more light per unit of current—reduce electric bills—Jefferson Transformers insure maximum economy.

# JEFFERSON TRANSFORMERS

## SIMPLIFY INSTALLATION

Industrial plants, steel mills, railroads—all industry are finding the new high efficiency of mercury lamps an immediate means of improving illumination and cutting electric bills in half.

Jefferson Transformers for use with these lamps insure the expected full rated capacity and satisfactory performance. They keep the current demand low during the starting period and on continuous operation show low temperature rise. A special core has been designed, made up of very thin laminations of high silicon steel, annealed after punching to prevent ageing, and to insure cool operation.

### Easy, "Screw-Driver" Installation

The terminal connections are easily made with a screwdriver,—no pigtails to solder.—And the wiring compartment covers have permanently attached screws to save time and loss.—Width and depth are smaller to improve appearance.

Jefferson's long specialized experience in the development of transformers for mercury and Neon luminous tubes, sun lamps, street lights and the like, makes possible the high quality special types of transformers and reactors required for these mercury lamps.

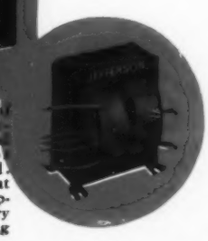
Available for use with both 250-watt and 400-watt lamps. Write or mail coupon for Bulletin 361-MV.

Wall Mounted Type in neat metal case for mounting on wall or post. Bottom is open for ready access to wiring compartment. Snap-on connections make it easy to match primary supply line voltage.

(Wall-mounted and fixture types are equipped with primary tap changing device and large primary and secondary wiring compartments.)

Fixture or Suspension Type for mounting between ceiling and lamp—with standard threaded coupling at each end.

Weather-proof Type in one piece drawn steel case—interior compounded. Connections at bottom. Equipped with primary tap changing device.



Core and Coil Type—which fits in fixture. Vacuumized, impregnated with final double varnish dip bake.

JEFFERSON ELECTRIC COMPANY
BELLWOOD (Suburb of Chicago) ILLINOIS
Canadian Factory: 535 College Street, Toronto

MAIL THE COUPON

**JEFFERSON** Mercury Vapor Lamp Transformers

JEFFERSON ELECTRIC COMPANY,
BELLWOOD, ILLINOIS

Please send Bulletin 361-MV and complete information on Mercury Lamp Transformers.

Name_____

Address_____

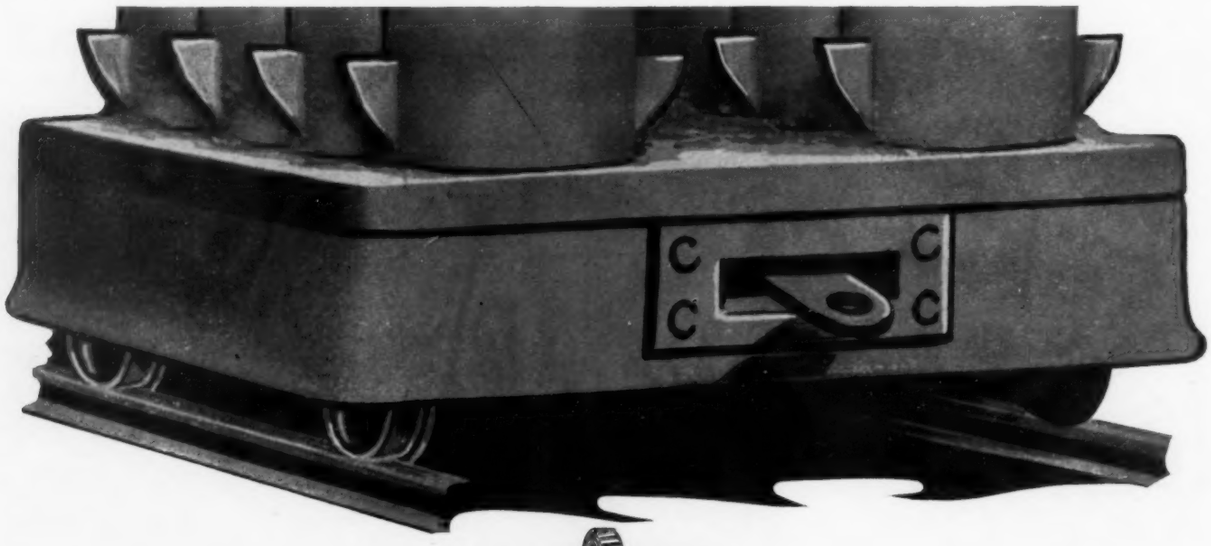
City and State_____

# FORD Operates 155 Ingot Cars on TIMKEN BEARINGS

No manufacturer has had a better opportunity than the Ford Motor Company to learn the relative merits of different types of bearings for any kind of industrial equipment.

Some of industry's toughest bearing jobs are found in the Ford steel plant. Take ingot cars for example. Ford ingot cars are designed to handle three sizes of ingots weighing respectively 1,500 pounds, 4,500 pounds and 20,000 pounds apiece—exclusive of the molds. With 8 ingots per car the load on the bearings is terrific—especially in the case of the cars which carry the 10 ton ingots—but Timken Bearings take it with the same sureness and dependability they display in modern railroad cars, locomotives and streamlined trains where the operating conditions are even more severe.

The new Ford hot strip mill is also Timken-equipped. Whether you are buying ingot cars, rolling mills, machine tools or any other kind of industrial equipment it will pay you to insist on Timken Bearings.



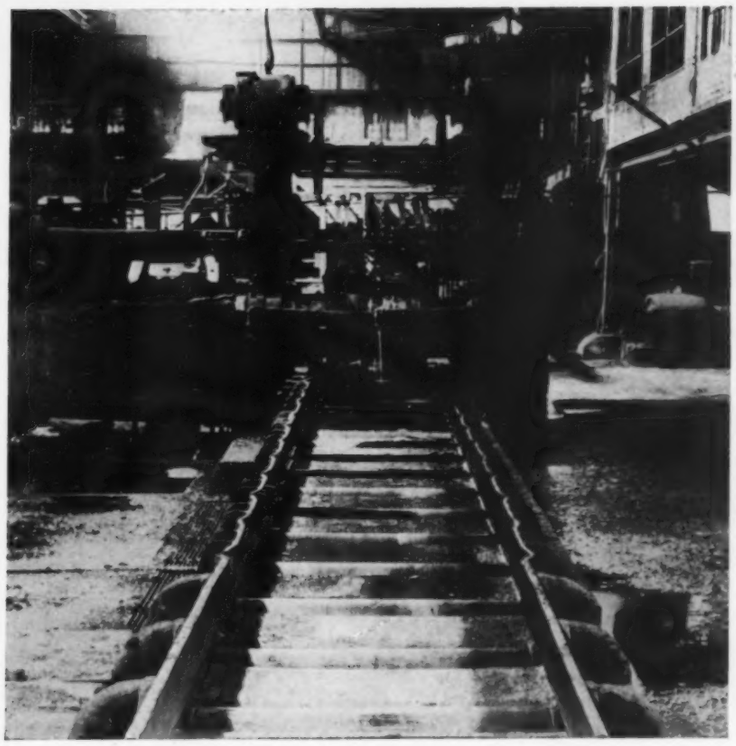
Tapered Roller
TIMKEN BEARING
EQUIPPED

A symbol of quality for any piece of equipment with which it is associated

THE TIMKEN ROLLER BEARING COMPANY, CANTON, OHIO

**TIMKEN** *TAPERED ROLLER* **BEARINGS**

SCHLOEMANN



MOTOR-ROLLERS
(SCHULTE PATENT)
Delay and high maintenance costs of reversing mill tables
are overcome by using Motor-Rollers

SCHLOEMANN
ENGINEERING CO.
Rolling Mill Machinery
PITTSBURGH, PA.
Hydraulic Presses

# Are *these* the LARGEST?

TORRENCE AVENUE
BRIDGE
CHICAGO, ILLINOIS

Span - - - 276 Feet
Weight - 3,220,000 Pounds
Lifts - - - 104 Feet

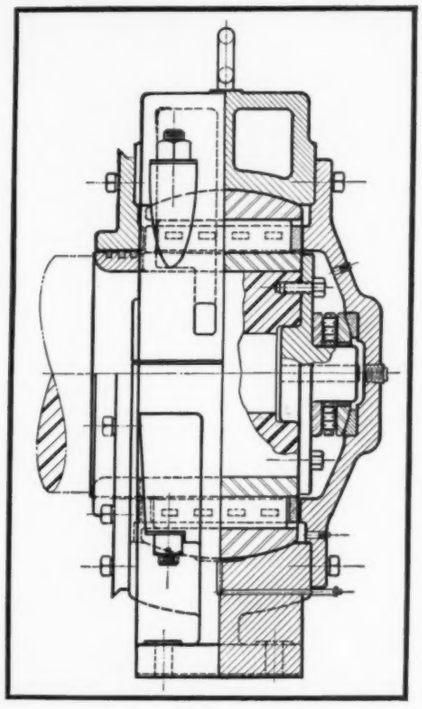
BEARINGS USED
BANTAM ROLLER
(Shown Below)

We believe these are the largest pillow block housings ever built for roller bearings. If they aren't — they must be near the top of the list.

Each unit weighs 22,500 pounds. Eight units totaling 180,000 pounds were built to house the Bantam Roller Bearings which raise the Torrence Avenue Bridge, now being completed in Chicago.

The fact that we were selected to do this job on both of the two large bridges in the United States operating on roller bearings, is just one more evidence of the advantage of coming to Bantam when there's a tough job to be done.

We shall be pleased to discuss yours! Let us hear from you.



BBB

## THE BANTAM BALL BEARING CO.

(SUBSIDIARY OF THE TORRINGTON CO.)

**SOUTH BEND, INDIANA**

CHICAGO
PHILADELPHIA
TOLEDO
CLEVELAND
PITTSBURGH
WASHINGTON, D. C.
DETROIT
MILWAUKEE
NEW YORK
ROCHESTER, N. Y.
HARTFORD
NEW ORLEANS
SEATTLE
INDIANAPOLIS

In Canada DOMINION ENGINEERING WORKS, LIMITED, MONTREAL

**TAKE YOUR TOUGHEST BEARING JOB TO BANTAM**

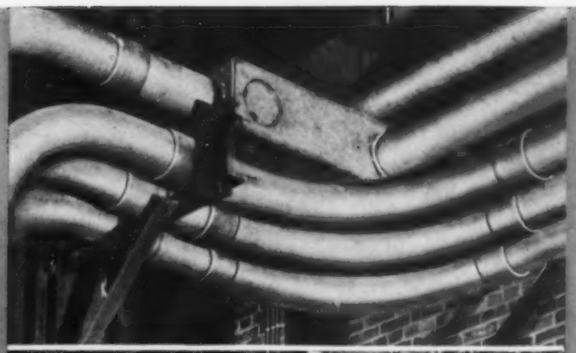
Johns-Manville

# TRANSITE ELECTRICAL CONDUIT

JM

—because steel-mill service demands

# AN ELECTRICAL CONDUIT THAT "CAN TAKE IT"



**IN EXPOSED LOCATIONS,** Transite's weatherproof quality assures years of maintained economy. This permanent material is also incombustible, unharmed by smoke or fumes.

**NO SPECIAL ENCASING** is required when Transite is installed under the floor of an industrial plant, as in this picture. Installation costs are reduced because Transite can be completely encased in the structural cement.

**UNDERGROUND,** Transite Conduit's strength cuts installation costs by eliminating the need for a concrete envelope. It is immune to electrolysis, soil corrosion, rot and decay.

## Permanent, economical, J-M Transite Electrical Conduit assures virtually maintenance-free performance under a wide variety of service conditions . . .

TRANSITE ELECTRICAL CONDUIT might well have been designed specifically for steel-mill service . . . so perfectly does it meet your most exacting requirements.

Asbestos-cement in composition, it offers the inherent advantages of these two imperishable minerals, permanent under all service conditions.

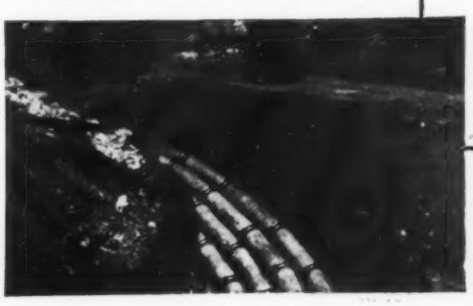
Underground, it goes down without a concrete envelope. Hence, by the elimination of concreting costs, Transite Conduit effects tremendous installation savings. And these economies are safeguarded through the years by Transite's high resistance to soil corrosion, imperviousness to rot and decay.

Above ground—in any exposed location—this same incombustible, weatherproof conduit is equally effective as a permanent, economical protection for your electrical-distribution systems.

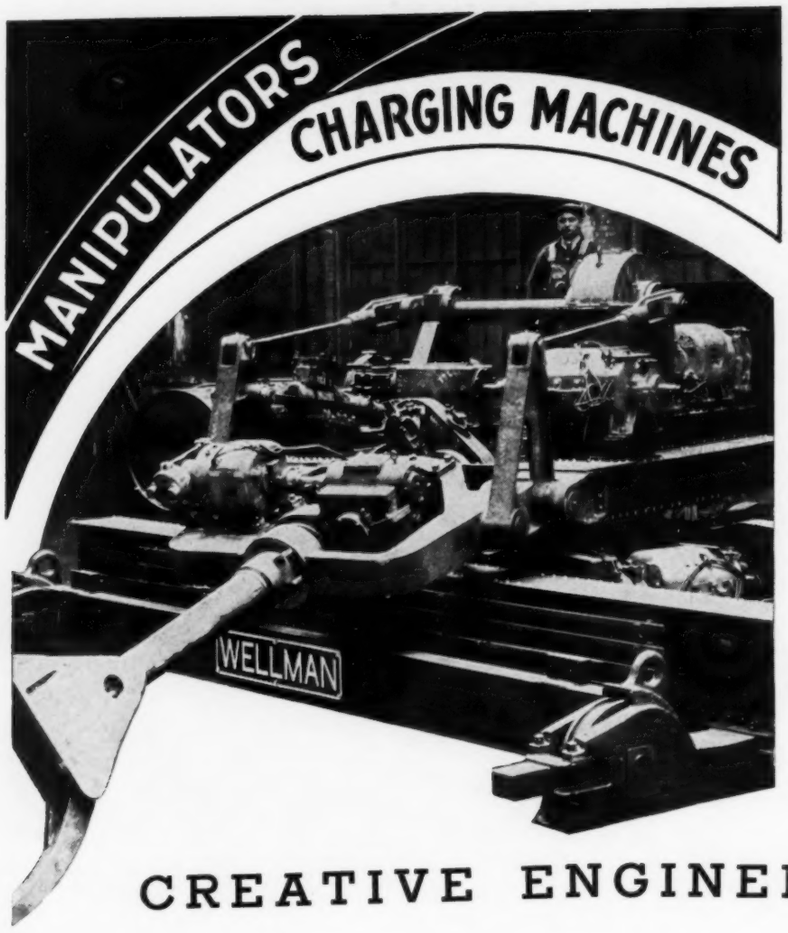
Furthermore, Transite Conduit has a low coefficient of friction; cables slip through without damage. And its rate of heat dissipation is high. For full details on Transite Conduit, and on Transite Korduct—our new lightweight conduit—described at the right, address Johns-Manville, 22 E. 40th St., New York City.

### When "concreting-in" is necessary—use J-M's new thin-walled Transite Korduct

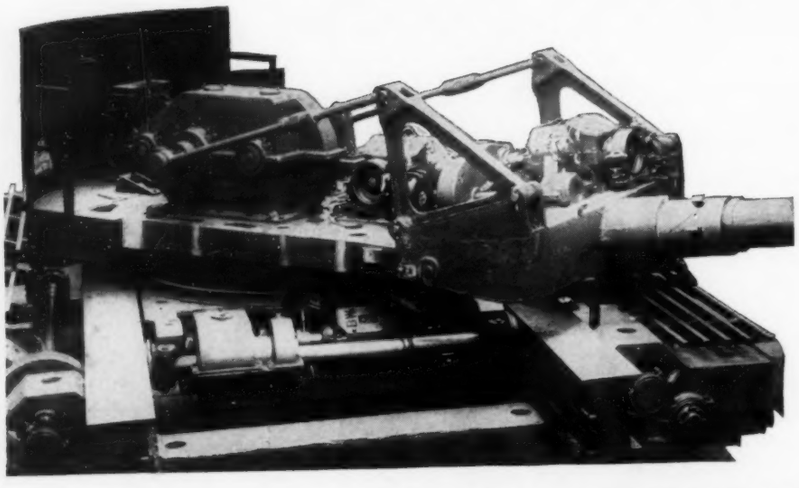
TRANSITE KORDUCT differs from Transite Conduit only in its lesser wall thickness. Like Conduit, it is asbestos-cement in composition . . . and guarantees the same inherent permanence and virtual freedom from maintenance. On jobs that demand a concrete envelope, Transite Korduct's light weight sizably cuts labor and handling costs.



**J-M TRANSITE KORDUCT** on a general-transmission 10-way duct line (2 tiers). Here, encased in concrete, it economically provides assurance of permanence at minimum maintenance.




# CREATIVE ENGINEERING!



Wellman ofiers you creative engineering with broad experience in mastering unusual problems.

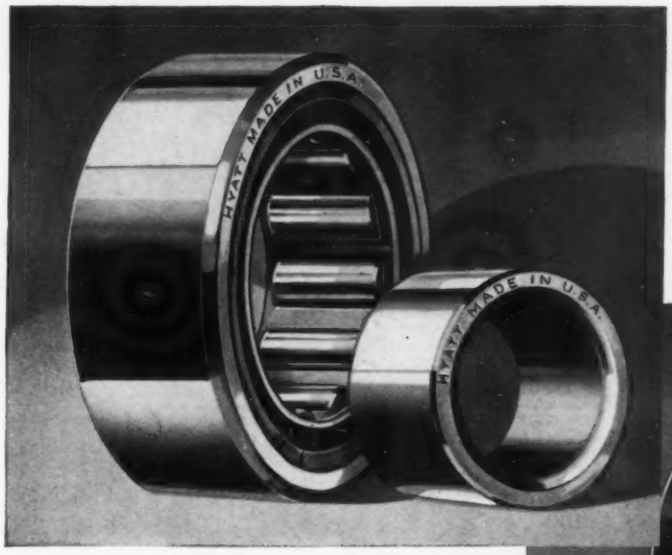
For instance, Wellman created the mechanically operated charging machine and the many outstanding developments in its modern efficiency and economy.

Without obligation, get Wellman's recommendations and figures on your next equipment needs.

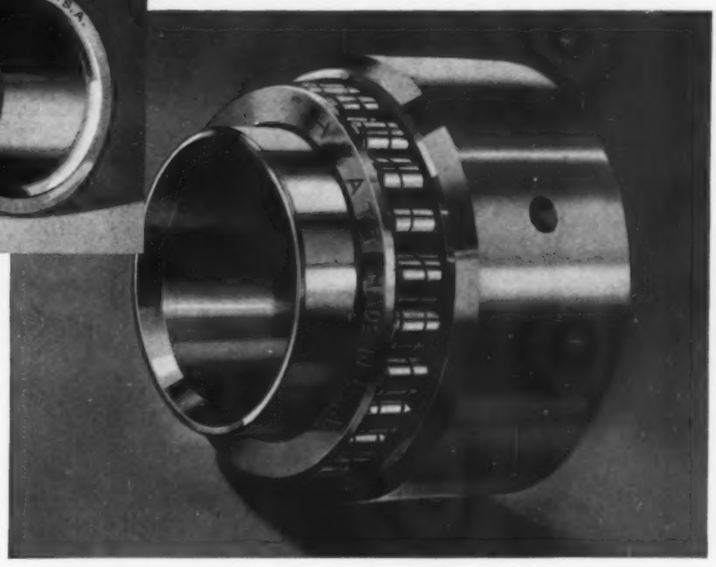
## WELLMAN PRODUCTS INCLUDE:

Steel Mill Equipment . . Charging Machines, Cars and Boxes . . Manipulators . . Coal and Ore Handling Bridges . . Gantry Cranes . . Special Cranes . . Clamshell Buckets . . Car Dumpers, all types . . Blast Furnace Skip Hoists . . Gas Producers, Flues . . Gas Reversing Valves . . Mining Machinery . . Safety Stops for Traveling Structures . . Welded Steel Construction . . Castings and Machine Work to customers' drawings.

THE WELLMAN ENGINEERING CO.
ENGINEERS CONSTRUCTORS MANUFACTURERS
WELLMAN
CLEVELAND, OHIO
BIRMINGHAM · NEW YORK · MEXICO CITY




There is a size and type of Hyatt Roller Bearing for every application. Machinery and equipment manufacturers build in Hyatts for better operation and longer life—but it pays to play safe and specify these dependable bearings by name.



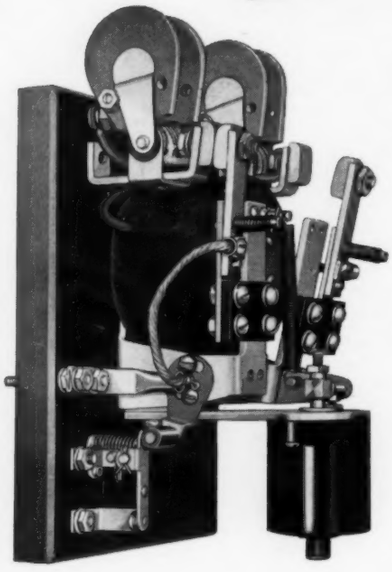
Illustrated above Hyatt Hyload Solid Roller Radial Bearing. At right, Hyatt Wound Roller Type.

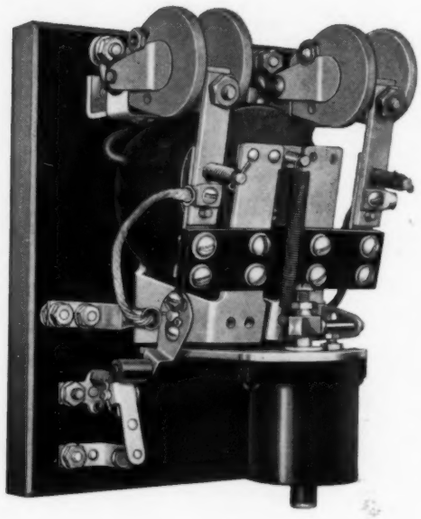
# KEEPING *Several* STRIDES AHEAD...WITH

# HYATT ROLLER BEARINGS

FROM the day anti-friction bearings were first applied, down through the years, each major development in machine design finds Hyatt out in front with improvements in bearing design, manufacture, performance. And, as time goes on, the basic Hyatt characteristics of greater precision, higher capacity, and smoother operation are constantly perfected. Not only has Hyatt kept pace in producing bearings to meet specifications, but many times has introduced application innovations. The ever-increasing use of Hyatt Roller Bearings, year after year, indicates how such diligence is richly rewarded. Hyatt Bearings Division, General Motors Corporation, Newark, Detroit, Chicago, Pittsburgh, San Francisco.

# CLARK-SUNDH Heavy Duty Industrial Control





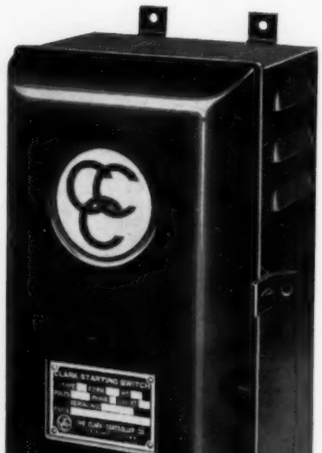
A 2-Step Starter with only one Magnet Coil.

In a Class with the Heavy Duty Mill Type Starters that you use with the larger D. C. Motors.

Overload protection included.

Furnished for either 2-Wire no-voltage release or for 3-wire no-voltage protection push button control.

Completely enclosed in sheet steel cabinet.



Rated up to and including 10 H.P., 230 volts, Non-Reversing.

Two forms: one for Jogging Service, one for Non-Jogging.

We have abused this new Baby, in test, all we know how.

Try it yourself and see what a "Husky" it is.

**THE CLARK CONTROLLER CO.**

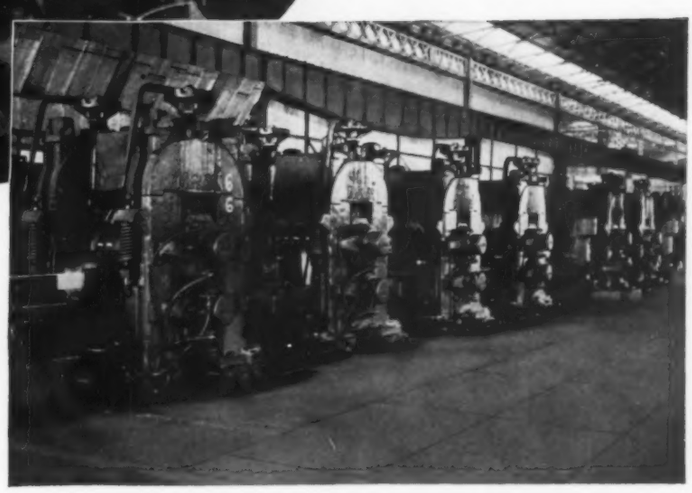
1146 E. 152ND ST.

CLEVELAND, OHIO

# A BIG MARKET

*but it carries*

## *a* BIGGER ONE



These cars represent only a small part of the great market offered the steel industry by the automotive manufacturers. But there is a greater market hidden in that picture.

Every automobile represents a home. And every home uses iron or steel wire by the mile: in sieves, dish drainers, bed springs, window screens—in thousands of modern conveniences no home can be without.

Made by the million, sold by the million, these modern devices call for efficient production, closer tolerances and greater uniformity in all the materials used. Greater uniformity in the rods, strips and merchant forms will increase production and profit all down the line. Yet you cannot compete in this exacting market if your rolling machinery is designed for the needs of 20-30-40 years ago. It is a new market representing tremendous profits for those who are in step with the demands of industry.

★ ★ ★

You can obtain the required tonnage with the desired accuracy only when your mill can function as a unit. Sound engineering knowledge plus years of experience are producing these results—in the modern Morgan Continuous Rolling Mills.

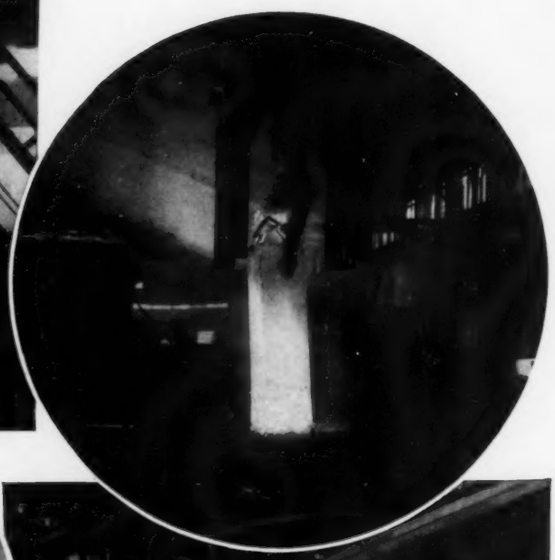
R-12

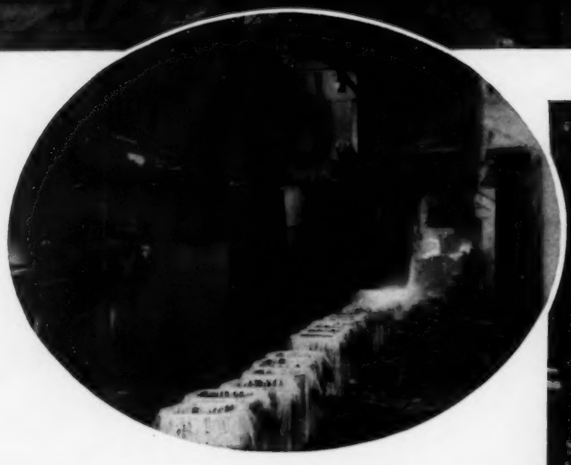
**MORGAN CONSTRUCTION CO.**

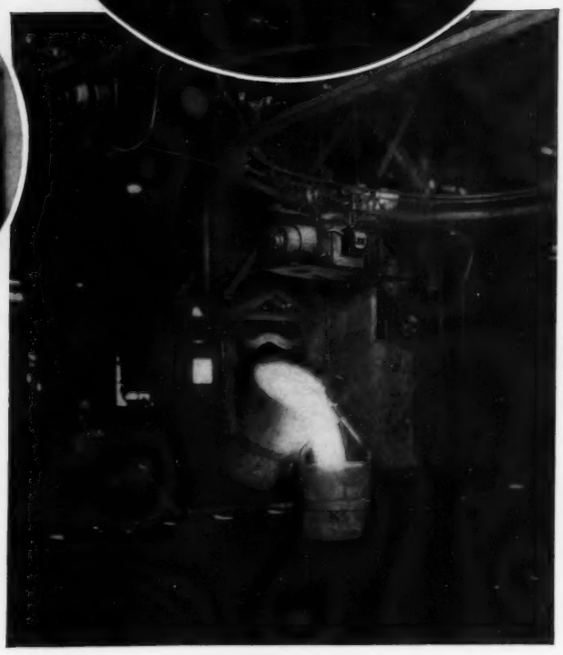
MORGAN WORCESTER ENGINEERS AND MANUFACTURERS

**WORCESTER MASSACHUSETTS**

# WHERE HEAT IS A PROBLEM







## DELTABESTON WIRE AND CABLE MAKE ALL POWER EQUIPMENT DEPENDABLE

Your motors may be subject to the most trying conditions. Excessive heat may be prevalent. Strenuous . . . month after month . . . operation may demand above-average service. In spite of this situation, profits depend upon unfailing power equipment.

Manufacturers, plant managers and engineers have found these very things true in their organizations. They have eliminated common causes of motor failure with Deltabeston. These superior wires and cables . . . insulated with PURIFIED ASBESTOS . . . have been subjected to your problems . . . and have solved them.

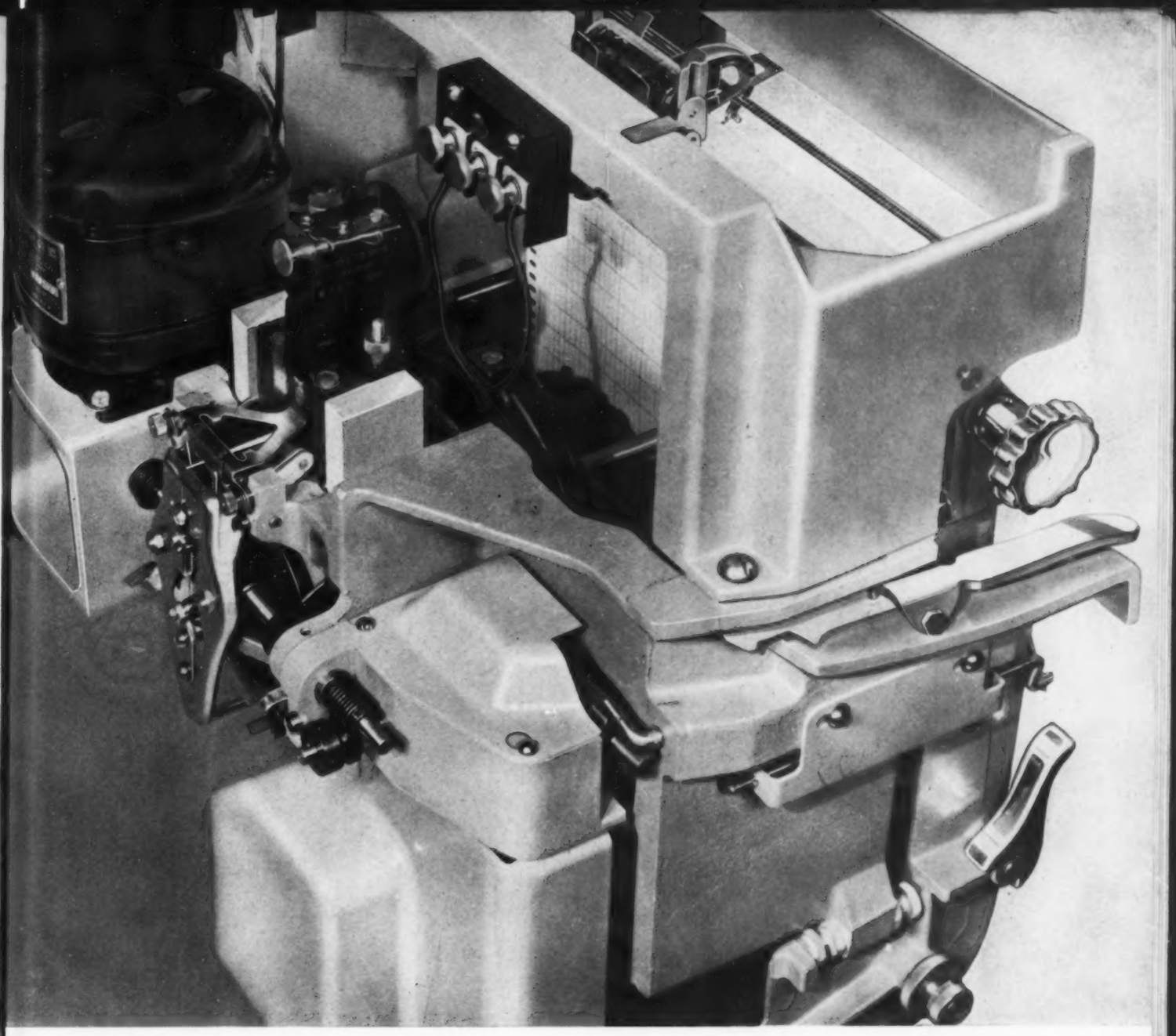
Wind motors with G-E Deltabeston Magnet Wire. The purified asbestos insulation is uniform . . . tough . . . durable. It resists heat . . . withstands abrasion. Then follow through with a quality job by using Deltabeston Asbestos-insulated Power Cable.

Complete information on Deltabeston Wire and Cable, Purified Asbestos, felted insulation — and its adaptability in your application will be sent upon request. Write Section Y-6412, Appliance and Merchandise Department, General Electric Company, Bridgeport, Connecticut.

# GENERAL ELECTRIC

**Deltabeston Wire and Cable**

**APPLIANCE AND MERCHANDISE DEPARTMENT, GENERAL ELECTRIC COMPANY, BRIDGEPORT, CONN.**



Micromax Recorder of 100 Uses—Mechanism swung out of its case

# *Reliability* . . . THE FIRST CONSIDERATION

Parts are strong machine types, unique in the instrument art. The materials of which they are constructed have been chosen as a result of exhaustive tests in actual service. Many are heat-treated . . . in Hump Vapocarb Furnaces. Factors of safety in all are large. Reliability is the first consideration.

J-N33(5)

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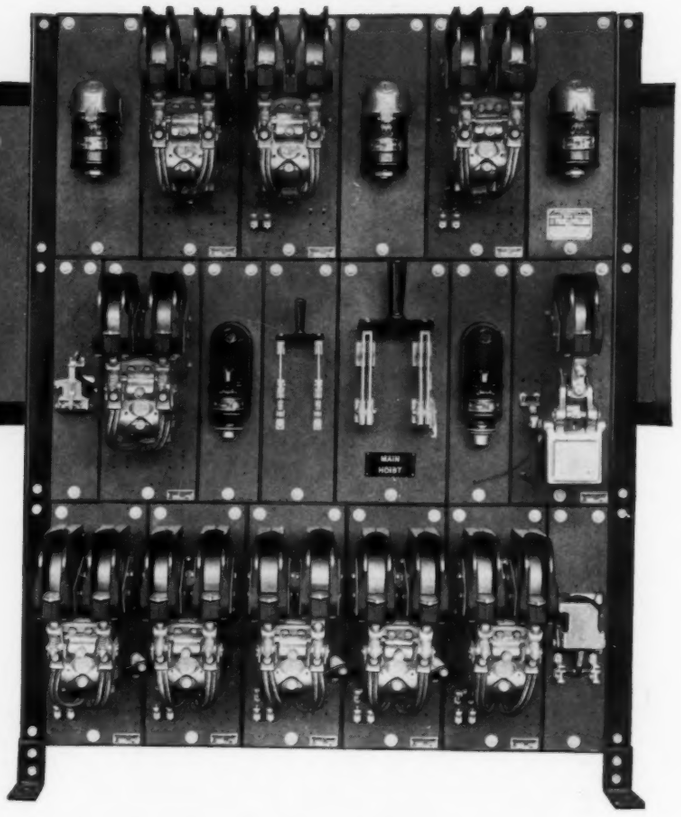
# 3 MAJOR IMPROVEMENTS IN CRANE CONTROL

**SCIENTIFIC CONTROL OF THE ARC**
**TIME-CURRENT METHOD OF ACCELERATION**
**MORE TRIPS PER MINUTE**
**with Less Power Consumption**



## Combined in this EC&M Controller

### Advantages of these 3 Major Improvements

LINE-ARC Contactors—a new standard of contact-life . . . no destructive burning of arc shields . . . quick response, because lightweight, high-strength aluminum alloy construction is used . . . current-carrying shunts, of individually tinned strands of wire, are correct length to eliminate whip and wear.

TIME-CURRENT Method of Acceleration—Operating characteristics similar to the series motor . . . gives quick acceleration when loads are light . . . longer time when loads are heavier . . . and, under abnormal conditions, forces acceleration, increasing motor torque until the load starts to move or if the motor can not start, causes the overload relays to trip.

THE WRIGHT DYNAMIC LOWERING CIRCUIT Magnetic Hoist Controller—Instantaneous Brake Release . . . high speed lowering of light loads or the empty hook . . . accurate spotting of heavy loads . . . reduced peaks of current . . . material saving in power on all loads at all speeds . . . greater return of power to the line when lowering overhauling loads . . . in short, More Trips per Minute with Less Power Consumption.

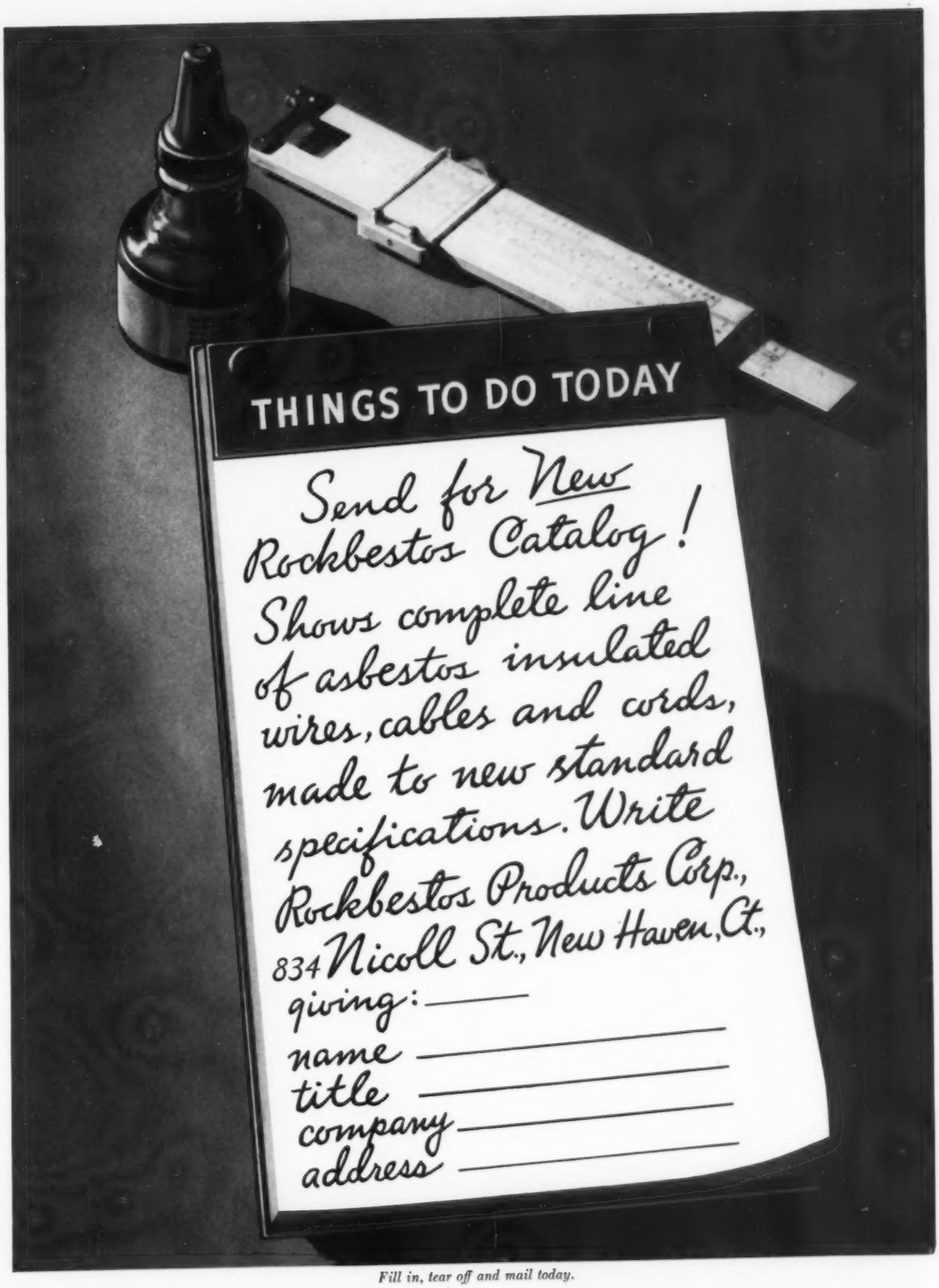
THE ELECTRIC CONTROLLER & MFG. CO. CLEVELAND, OHIO

**HEAVY DUTY MOTOR CONTROL FOR CRANES, MILL DRIVES AND MACHINERY • BRAKES • LIMIT STOPS • LIFTING MAGNETS AND AUTOMATIC WELD TIMERS.**

The primary functions of a controller are:

1. **To regulate starting, acceleration and running so as to secure the maximum output of the driven machine.**
2. **To protect the motor and machine and guard them against abnormal conditions which cause expensive delays.**
3. **To operate for long periods of time before replacements are required and, when they are necessary, to permit quick renewal.**

In EC&M Control, these functions of a controller are given major consideration. It is because of the attention to these important requirements that many firms select EC&M Control for their new cranes or for use in the revamping of their old ones. Thousands of cranes equipped with EC&M Control testify to this fact. Bulletin 920 describes and gives proof of the advantages of this advanced and modern control for cranes. Write today for your copy.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Send for New Rockbestos Catalog! Shows complete line of asbestos insulated wires, cables and cords, made to new standard specifications. Write Rockbestos Products Corp., 834 Nicoll St., New Haven, Ct., giving:
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*Fill in, tear off and mail today.*

LABEL ALCOA ALUMINUM BUS BAR *Economical*

Above, the main bus in this switchroom was installed 22 years ago, in 1914, and the jumpers seen in the foreground were installed 7 years ago, in 1929. The operating record shows "continuous, trouble-free service." Both the main bus and the jumpers are Alcoa Aluminum.

To say that an Alcoa Aluminum Bus System costs less is to say that it is better, if you include the whole picture.

Here, in a few words, is the picture: Alcoa Aluminum bus is 52% lighter. Since it is more easily handled, and more easily formed, installation costs less. Often runs may be placed high, conserving floor space and adding to convenience, without constructing special supports. Spans between supports can be longer. Splices, taps and joints are easily welded, or bolted. Fittings are simple and inexpensive.

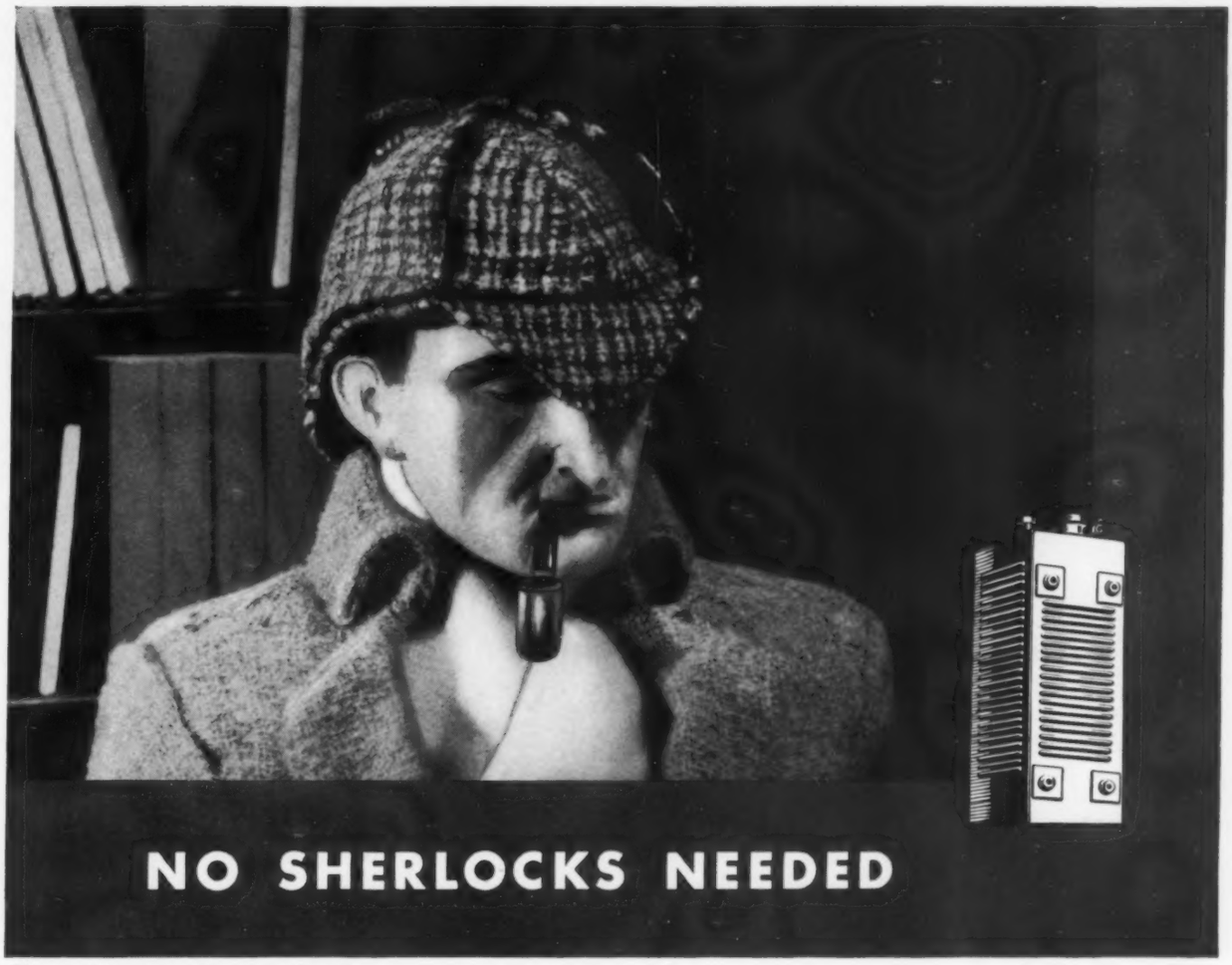
For special problems Aluminum bus has special answers. Because it is naturally corrosion resistant, it is suited to plating room installations and other uses where corrosive fumes may cause trouble. When mechanical strength is needed, Channeluminum, the rolled Channel section, provides maximum physical strength, as well as the ultimate in electrical and thermal efficiency.

These advantages are all dollars-and-cents advantages; you can put the mental tag "Economical" on your conception of Alcoa Aluminum bus bar. And when you want actual figures and data, write to ALUMINUM COMPANY OF AMERICA, 2128 Gulf Bldg., Pittsburgh, Pa.

ALCOA

REG U. S. PAT. OFFICE

ALCOA · ALUMINUM




*Photograph courtesy of Ticonderoga Pencils*

The steel industry understands all about the advantages of a steel storage battery for industrial truck and tractor work. No Sherlocks are needed because the facts are obvious. Steel batteries last 2 to 5 times longer than ordinary batteries, because steel is durable. They are less subject to damage, because steel is tough. They require less maintenance, because their alkaline electrolyte is a preservative of steel. In other words, they supply the very qualities required for heavy-duty service. ● Foremost, however, is the fact that Edison Storage Batteries do the work expected of them with minimum danger of unexpected failure. Such failure could cause thousands of dollars in delayed production. That more than 70% of the heavy-duty batteries in the steel industry are Edisons, shows that steel men regard them as outstanding examples of the suitability of steel where ruggedness, light weight, and dependability are needed.

# EDISON STORAGE BATTERY

**DIVISION OF THOMAS A. EDISON, INC., WEST ORANGE, NEW JERSEY**

# POOLE

## Flexible Couplings

**ALL METAL** **FORGED STEEL**

**NO WELDED PARTS**

The Poole flexible coupling combines great mechanical strength with an unusual capacity for adapting itself to ordinary shaft misalignments. It has no springs---rubber---pins---bushings---die castings or any flexing materials that require frequent replacement.

Using strong specially treated steel forgings, long wearing gears in constant bath of oil, this coupling eliminates your coupling troubles.

**OIL TIGHT---DUST PROOF---FREE END FLOAT---**
**FULLY LUBRICATED**

*Send for a copy of our Flexible Coupling Handbook.*

## Poole Foundry & Machine Company

**Baltimore, Maryland**

# PRECISION BEARINGS
## in 108 distinct series

To the machinery world, NORMA-HOFFMANN offers the most complete and comprehensive line of anti-friction bearings in America—108 distinct series—a PRECISION Bearing for every load, speed and duty.

Many of these have been pioneered, or specially developed, by NORMA-HOFFMANN engineers to meet specific requirements as revealed by advancing methods in machine design, manufacture and operation.

In times past, engineers often had to adapt their designs to the comparatively few standard bearing types then available. Today—with the wide range of types and sizes afforded by the standard NORMA-HOFFMANN PRECISION line, such compromise is seldom necessary.

In the 108 PRECISION Series are included: ball, roller, needle and thrust bearings; open, closed, and angular contact bearings; radial and self-aligning types; single and double row types; felt-protected, shielded, snap ring and self-sealed types. The size range is from 1/8- to 21-inch bore, embracing both metric and inch sizes. PRECISION Ball and Roller Bearing Pillow Blocks are also available in an extensive range of sizes.

*Write for the Catalog. Let our engineers work with yours.*

**"NORMA-HOFFMANN"**

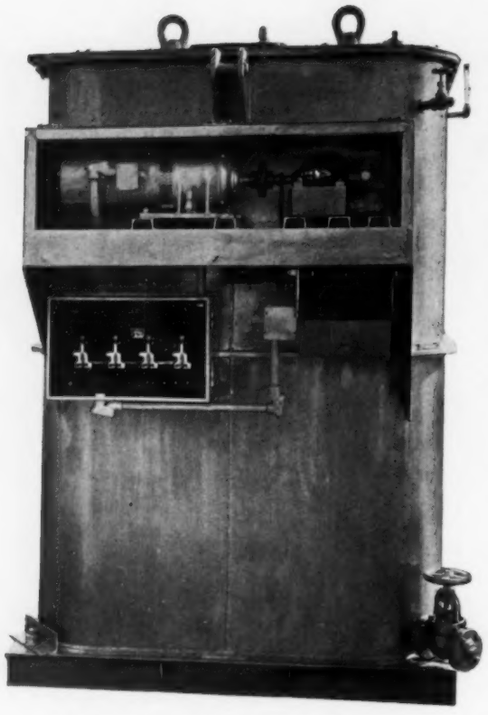
**PRECISION BEARINGS**

**BALL. ROLLER AND THRUST**

**NORMA-HOFFMANN BEARINGS CORPN., STAMFORD, CONN. U.S.A.**

A-3127

# *For* Heavy Industries



● Large Furnace Transformer equipped with tap changers which are operated by remote control

● Heavy Industries are increasingly depending on Pennsylvania Heavy Duty Transformers. Our modern plant with improved facilities enables us to build transformers up to 25,000 KVA capacity. *Call on Pennsylvania to help you solve your problems.*

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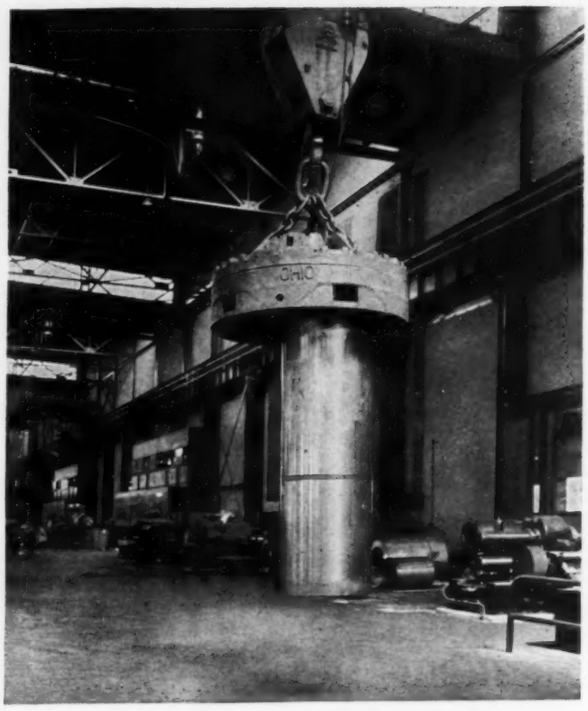
Pennsylvania Transformer Co.
1701 Island Ave., N. S., Pittsburgh, Pa.

PENNSYLVANIA TRANSFORMERS

# OHIO




Special Design to lift coils of Strip Steel VERTICALLY.

**OHIO LIFTING MAGNETS**—Of improved design giving Maximum All Day Lifting Capacity

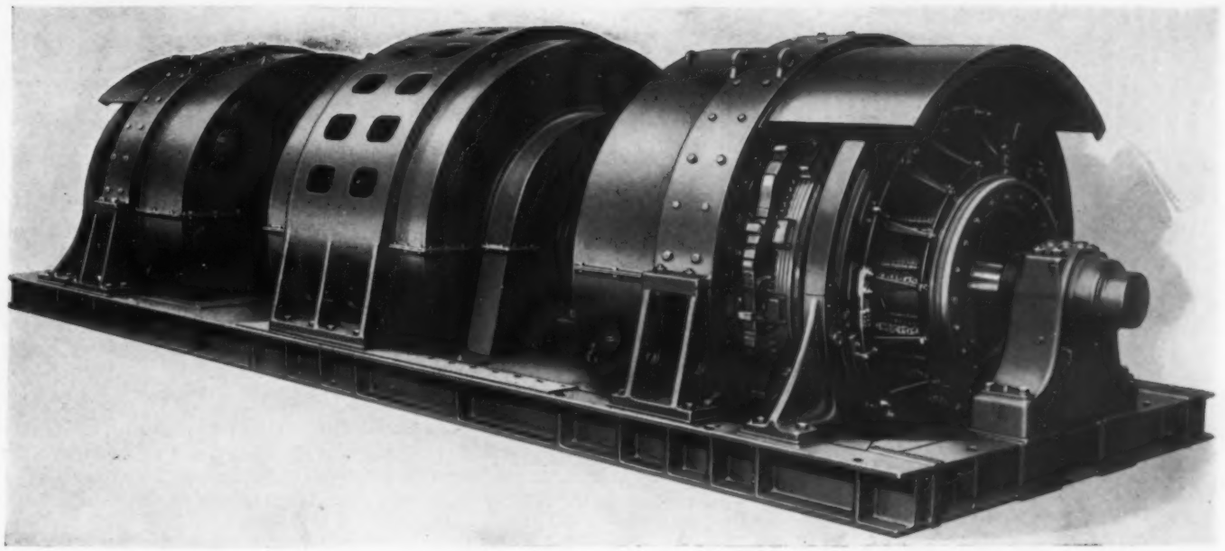
**OHIO SEPARATION MAGNETS**—With Stronger Pulling Capacity.

**OHIO MAGNET CONTROLLERS**—With Automatic Quick Drop to speed up operation and With Ohio Arc Suppressor to reduce the arc and make the Contacts and Arc Shields last much longer.

Ask for new Bulletin No. 109

## THE OHIO ELECTRIC MFG. CO.

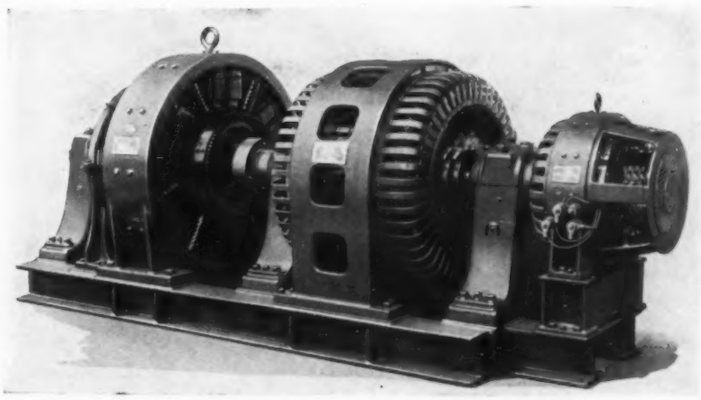
5907 Maurice Avenue Cleveland, Ohio



# EXCELLENT COMMUTATION

## ... under heavy overloads makes these M-G Sets particularly suited for Strip Mill Service

The Synchronous Motor Generator Set shown above, for supporting finishing stand mill motors in a new strip mill has a rating of 6,000 kw, 600 volts d-c, 3 phase, 60 cycle, 6600 volts, 360 rpm. The armature conductors are laminated, using Vega insulated strands. It was built, along with two others of a similar rating, for a steel mill in the Chicago area.



Oscillograms showed the entire absence of voltage ripples in the coils under commutation as well as a uniform voltage generated in the coils while under the main poles. These were clear indications of the excellent commutation that took place.

After carrying a full load continuously for one week, the 3,000 kw, 600 volt, generators carried 200 per cent load at rated voltage with absolutely sparkless commutation.

**ALLIS-CHALMERS ENGINEERED**

Blowers and Compressors.
Cement-making Machinery, Rock Crushers, Screens, Road-building Equipment.
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Electric Generators, Transformers, Converters, Rectifiers, Switchgear, and Regulators . . . Electric Motors for all purposes.
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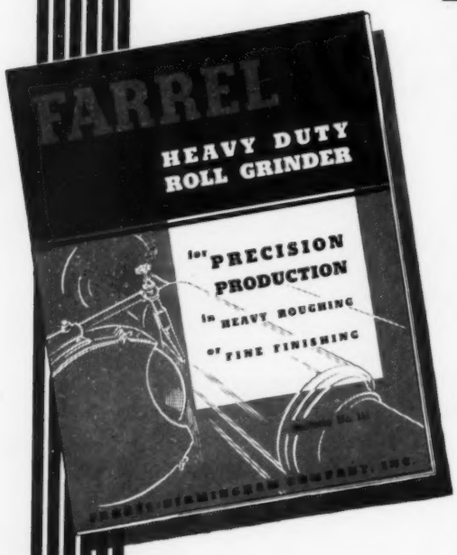
*Bulletins for various types of equipment furnished on request.* *Address Allis-Chalmers Mfg. Company, Milwaukee, Wis.*

# To Users of ROLLS




If you want to improve the accuracy and finish of your rolls and at the same time grind them faster and cheaper, our new Bulletin No. 111 will be of interest.

This contains much useful information on roll grinding and explains the features of design and construction of the Farrel Heavy Duty Roll Grinder which are responsible for its exceptional *FIVE POINT PERFORMANCE.*

In addition to tabulations giving general specifications and dimensions and weights, the bulletin also describes the standard and optional attachments which can be furnished, and the electrical equipment required.

Thirty-seven illustrations include photographs of different sizes of roll grinders, close-up views of various units and installations of Farrel machines. A typical foundation plan shows how the foundation is constructed.

Bulletin No. 111 will be helpful to engineers, production executives and plant operating men who are responsible for the quality and output of metal finishing rolls.

Get your complimentary copy by filling out and mailing the attached coupon today.

**FARREL-BIRMINGHAM CO., INC., 42 Main St., Ansonia, Conn.**

Without obligation on my part, send me your new Bulletin No. 111 on Roll Grinders.

Name.....Title.....

Company.....

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## FARREL-BIRMINGHAM COMPANY, INC.

**42 Main St., Ansonia, Conn.**

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● **Open hearth furnaces pay a greater return on the investment when equipped with Bailey Control. This air-operated control system automatically maintains constant Furnace Pressure and most economical Fuel—Air Ratio consistent with furnace life.**

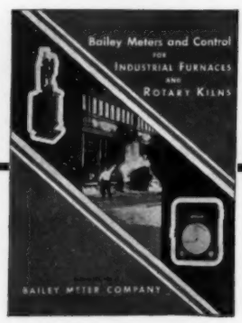
**Peak flame temperature is assured by Bailey Control as the result of correct excess air for combustion and reduction of unregenerated air infiltration to a minimum. Rapid deterioration of refractories is prevented prolonging the length of campaigns. The number of b. t. u. per ton of steel is lowered.**

**Details on how Bailey Control can shorten heats, lengthen campaigns, and decrease fuel consumption of your open hearth furnaces will be furnished upon request.**

*Mail coupon today*

*Send for this New Bulletin*

# BAILEY OPEN HEARTH CONTROL




S-5

**BAILEY METER COMPANY**
**1047 IVANHOE ROAD, CLEVELAND, OHIO**
**CANADIAN ADDRESS • MONTREAL, CANADA**

**Gentlemen: Kindly send me a free copy of Bulletin No. 104 describing Bailey Open Hearth Furnace Control.**

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**Company**.....

**Street**.....

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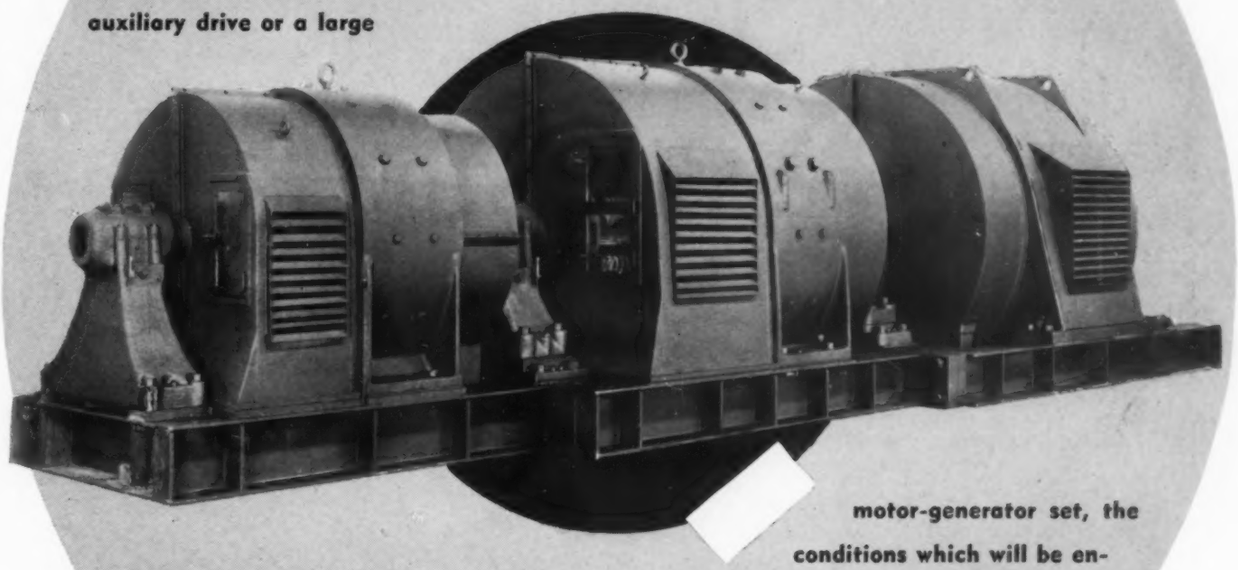
# Built to suit your requirements

EACH Crocker-Wheeler motor, each generator, each motor-generator set is individually designed and built for the particular application. Whether it is a small motor for auxiliary drive or a large



motor-generator set, the conditions which will be encountered after installation are all carefully considered before any recommendations are made. It is through strict adherence to this practice that Crocker-Wheeler has earned its reputation for "excellent engineering."

**CROCKER-WHEELER ELECTRIC MFG. CO.**
AMPERE, N. J.
*Sales offices in principal cities*

CROCKER-WHEELER

EXCELLENT ENGINEERING

# THEY MUST GIVE *Satisfaction*

Blooming Mill Motors

Commutating Type, Polyphase A. C. Motors

Mine Hoist Motors

Mill Drive Generators

Elevator Traction Motors

Synchronous Rotary Converters

Turbo-Alternator Exciters

Electric Shovel Generators

★ Increasing application over a constantly broadening field is convincing evidence that a product is giving satisfaction. Sales of SA Series Grades continue their rapid growth. The range of service in which these grades have established superiority is steadily expanding. They DO give satisfaction.

★ SA Series Grades are the product of an exhaustive research program which determined and incorporated in this product the characteristics essential to satisfactory performance on commutating equipment. For this reason, they are uniform in *performance* as well as in *physical characteristics*.

*PROVE THEIR SUPERIORITY BY A TRIAL!*

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*with* TRADE MARK NON-FLUID OIL REGISTERED IN U.S. PAT OFFICE & FOREIGN COUNTRIES

**Grease lubricants usually separate when forced into fittings at high pressure. NON-FLUID OIL does not change, so cannot produce harmful non-lubricating residue to clog bearings and fittings.**

**Because NON-FLUID OIL retains its normal oiliness permanently, it lubricates dependably until entirely consumed. Lasts longer, so needs to be applied less often.**

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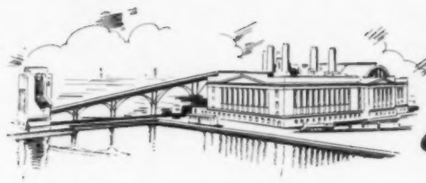
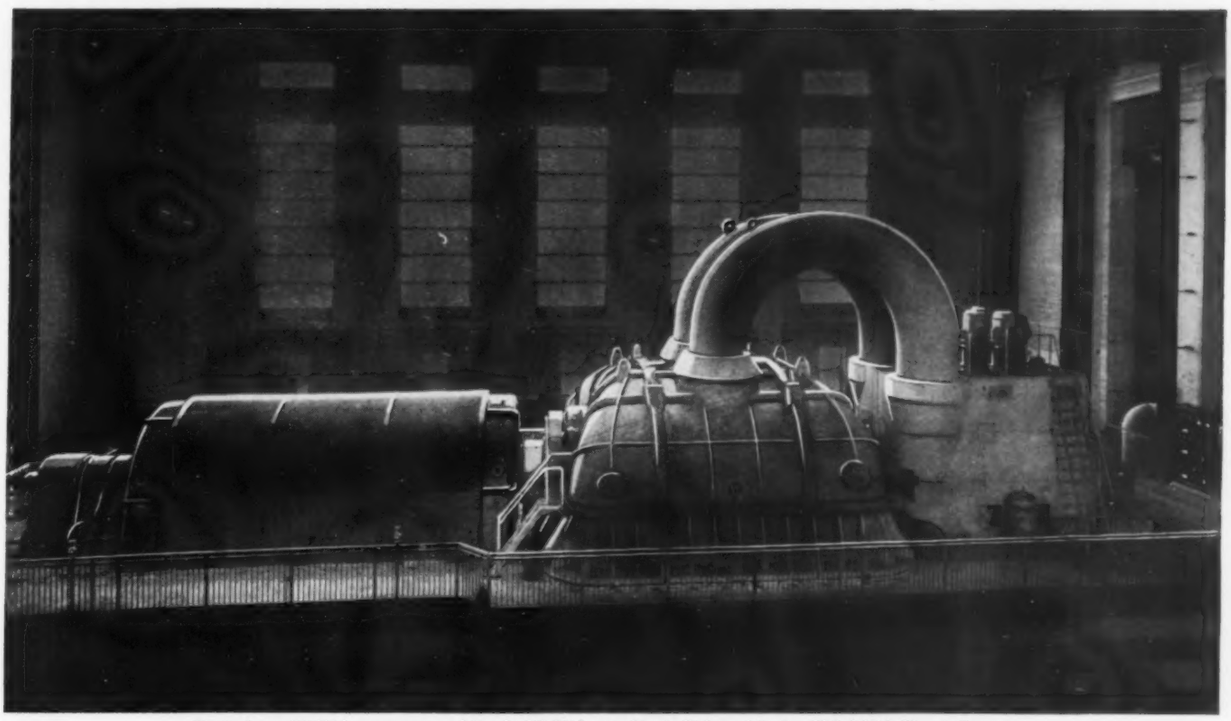
**MODERN STEEL MILL LUBRICANT**

*Better Lubrication at Less Cost per Month*



# Sturtevant Fans Serve

## WORLD'S LARGEST SINGLE SHAFT TURBO-GENERATOR



Westinghouse 183,333 kv.-a. generator, driven by 225,000 h.p. turbine in Richmond Station, Philadelphia Electric Company.

## . . at Richmond Station . . Philadelphia Electric Co.

Four Sturtevant Self-cleaning Induced Draft Fans serve the 2 Babcock & Wilcox 600,000 lb. per hour pulverized-coal-fired boilers for this world's-record turbo-generator. They are rated 190,000 c.f.m. at 380°F. against 14.5 static pressure. Speed: 850 R.P.M.

Eight other Sturtevant Turbovane Fans are used for primary air and pulverized coal mill service.

The addition to Richmond Station in which these Sturtevant Fans are installed was designed and constructed by United Engineers and Constructors, Inc., in cooperation with engineers of Philadelphia Electric Company.

Sturtevant Turbovane Induced Draft Fans.

B. F. STURTEVANT COMPANY, Hyde Park, Boston, Mass.
*Branches in 40 Cities* B. F. Sturtevant Co. of Canada, Ltd.—Galt, Toronto, Montreal

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REG. U. S. PAT. OFF.
*Puts Air to Work*

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**BY ONE OF AMERICA'S LARGE STEEL COMPANIES**

Every Uptegraff Transformer embodies precision of design and the highest quality materials obtainable. You will find Uptegraff Transformers in use where ruggedness and ability to withstand severe service are required.

Six Uptegraff Transformers: Single Phase, 60 Cycle, Oil Immersed having Junction Boxes on both primary and secondary for connections to conduit and lead cable. 6600 Volts Primary—115 / 230 Volts Secondary. Total shipping weight approximately 33,000 lbs.

*Tell us your transformer requirements. We build every type up to 5,000 KVA.*

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**300 No. Lexington Avenue, PITTSBURGH, PA.**

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### Alliance Products

**STANDARD CRANES**
**Up to 430 tons capacity**

**STRIPPING CRANES**
**Up to 320 tons capacity**

**COMBINATION CHARGERS and STRIPPERS**
**Up to 200 tons capacity**

- Ladle Cranes
- Ingot Strippers
- Soaking Pit Cranes
- Open Hearth Charging Machines
- Slab and Billet Charging and Drawing Machines
- Gantry Cranes
- Ore and Coal Bridges
- Car Dumpers
- Forging Manipulators
- Board Drop Hammers
- Steam Drop Forge Hammers
- Coke Pushers, Levelers and Door Lifters
- Coal Pier Equipment
- Rolling Mill Machinery
- Cement Plant Machinery
- Dock Handling Equipment
- Coke Oven Equipment

### *275 of 100 Tons Capacity and Over*

**LADLE AND STANDARD CRANES**

| | | |
|---|---|---|
| 59 | | 100 tons |
| 2 | WORM DRIVEN Ladle, | 100 tons |
| 2 | | 115 tons |
| 6 | WORM DRIVEN Ladle, | 125 tons |
| 45 | | 125 tons |
| 30 | | 150 tons |
| 3 | WORM DRIVEN Ladle, | 150 tons |
| 6 | WORM DRIVEN Ladle, | 160 tons |
| 2 | WORM DRIVEN Ladle, | 165 tons |
| 7 | WORM DRIVEN Ladle, | 175 tons |
| 27 | | 175 tons |
| 3 | WORM DRIVEN Ladle, | 200 tons |
| 4 | | 200 tons |
| 5 | | 225 tons |
| 1 | | 250 tons |
| 3 | WORM DRIVEN Ladle, | 250 tons |
| 3 | WORM DRIVEN Ladle, | 275 tons |
| 1 | | 275 tons |
| 1 | | 300 tons |
| 3 | | 430 tons |

**STRIPPING CRANES**

| | | |
|---|---|---|
| 8 | | 100 tons |
| 1 | | 125 tons |
| 22 | | 150 tons |
| 19 | | 200 tons |
| 1 | Single Ram, | 320 tons |

**COMBINATION CHARGERS AND STRIPPERS**

| | | |
|---|---|---|
| 3 | | 100 tons |
| 1 | | 125 tons |
| 3 | | 150 tons |
| 4 | | 200 tons |

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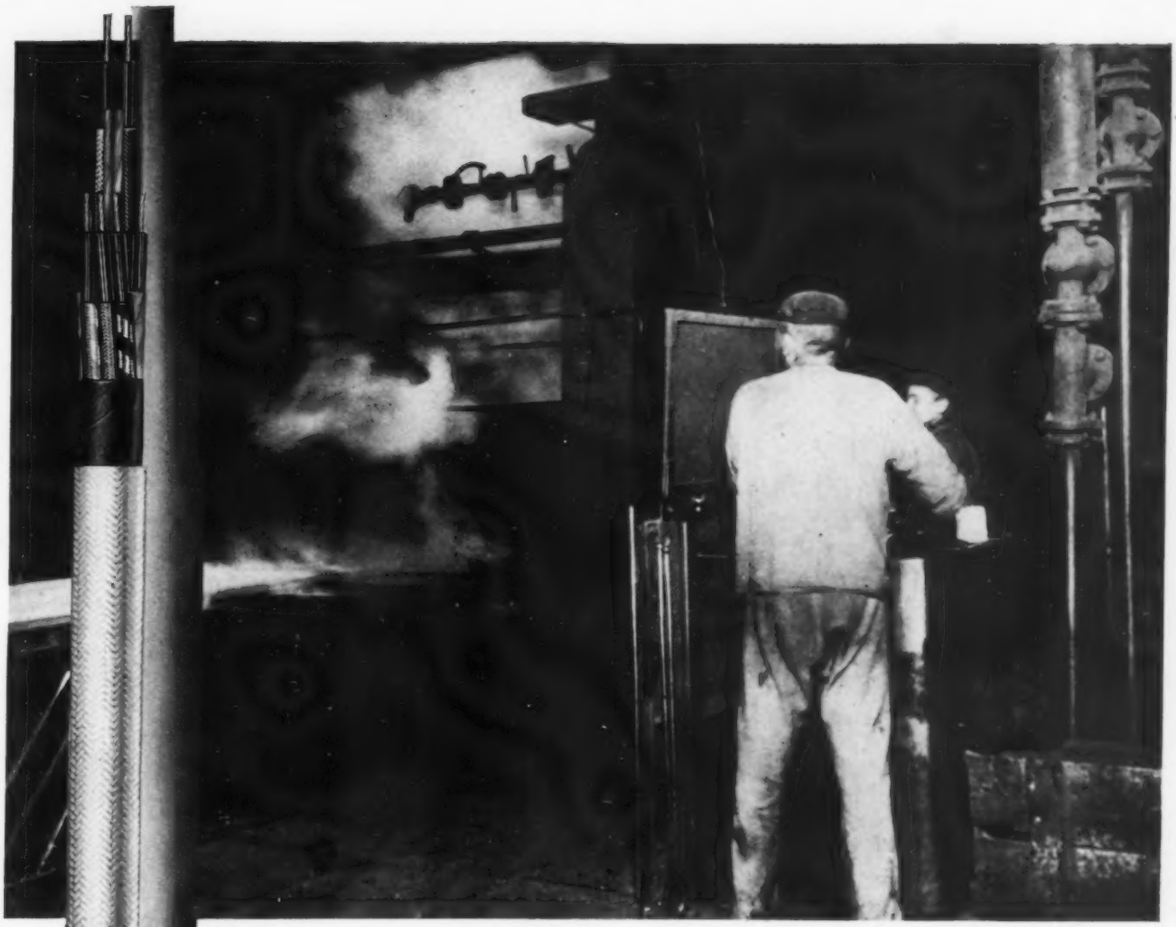
*ENGINEERS AND BUILDERS*



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Founded 1878

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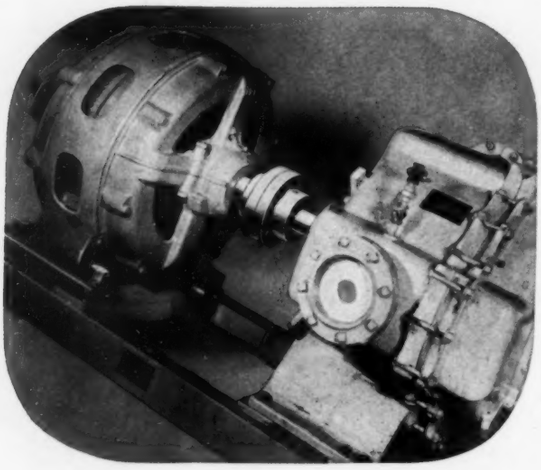
Factories: Passaic, N. J. Wilkes-Barre, Pa. Paterson, N. J.

OKONITE QUALITY CANNOT BE WRITTEN INTO A SPECIFICATION

» Ajax «

INSTALLATION
ON HIGH-VACUUM PUMP



For all pump drives, A J A X is the natural, the only coupling to use.... What pump drives demand, only AJAX is prepared to give: 24-hour operation---no shut-downs or repairs---no stops for lubrication---constant, flawless service year after year....What problems pump drives set up, AJAX is prepared to solve: uneven, pulsating load to be transmitted smoothly---free end play of shafts allowed by AJAX'S complete lack of end thrust and negligible amount of friction.

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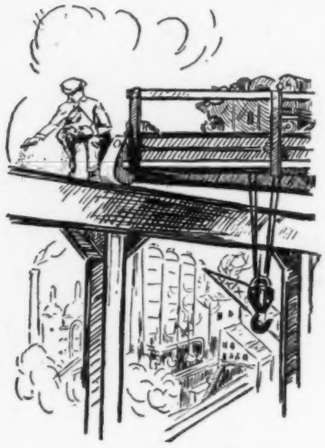
Dangerous



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SAFE, MODERN

LINTERN SANDERS

**This automatic sander has replaced the old-time dangerous method of having a man balance himself on a slippery rail while trying to spread sand for the crane—a practice which often resulted in injury or death.**

**The Lintern Electro-Magnetic Sander is built to operate under most severe mill or weather conditions. It promotes efficiency of equipment and assures safety for men.**

**Many of these sanders, 15 years old, are in use today without other attention than an occasional filling with sand.**

**Avoid accidents these dangerous winter days—ask for Catalog E-4.**

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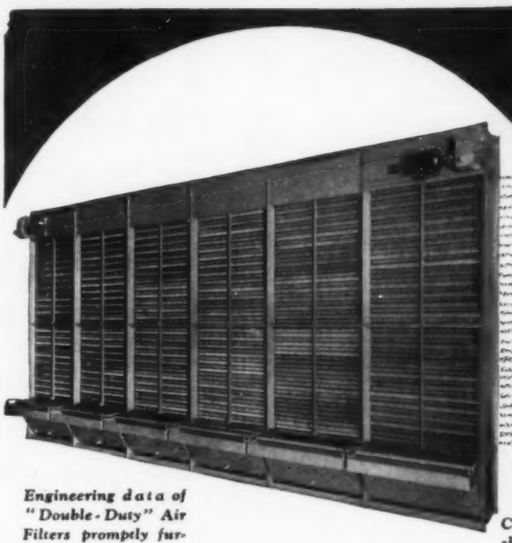
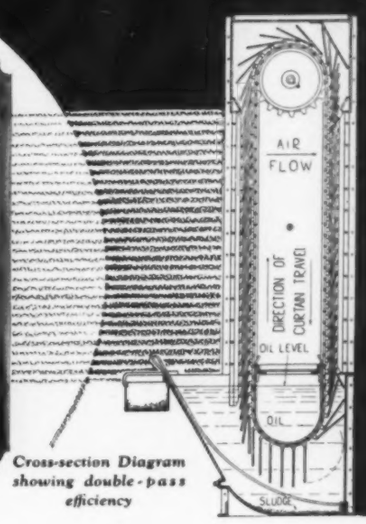


*Engineering data of "Double-Duty" Air Filters promptly furnished upon request.*




*Cross-section Diagram showing double-pass efficiency*

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**OUTSTANDING DOUBLE DUTY FEATURES**

All Steel Construction

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True Impingement Principle

Uniform Air Flow

Standardized Sectional Design

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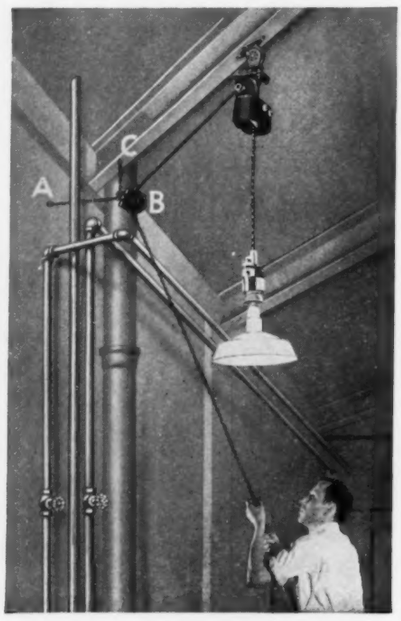


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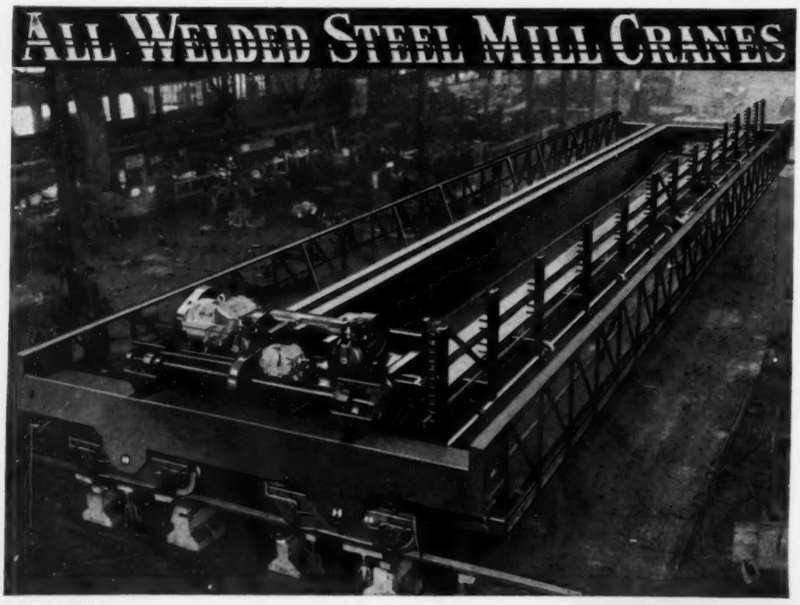


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Shop assembly: One of five duplicate 120 foot span All Welded Roller Bearing Cleveland Cranes.

ALL Welded Steel Mill Cranes with Roller Bearings in all Sizes and Types and for any kind of Service.

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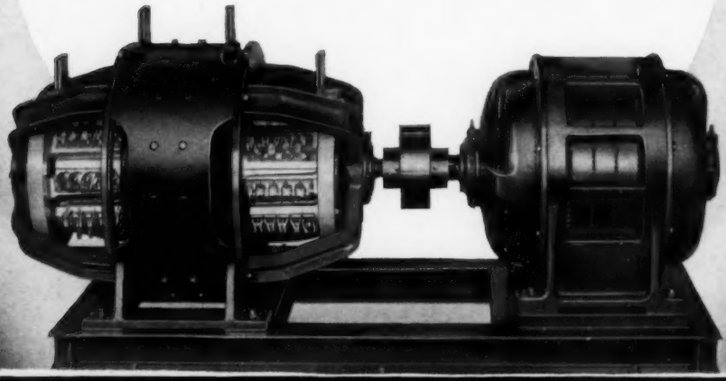

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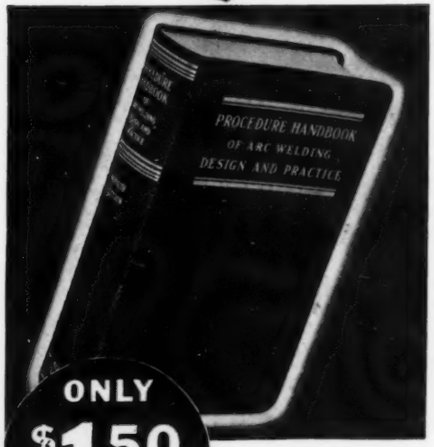


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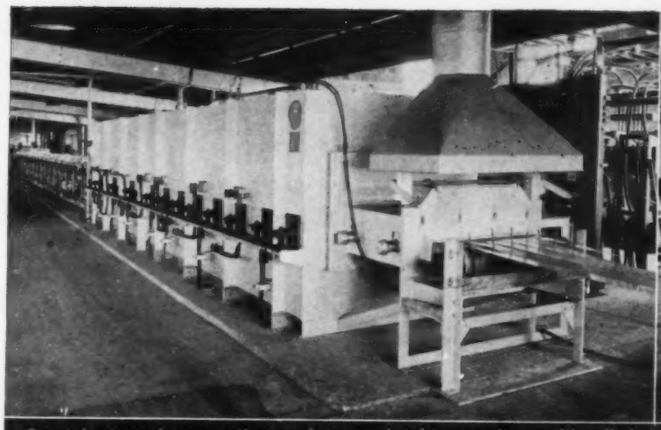
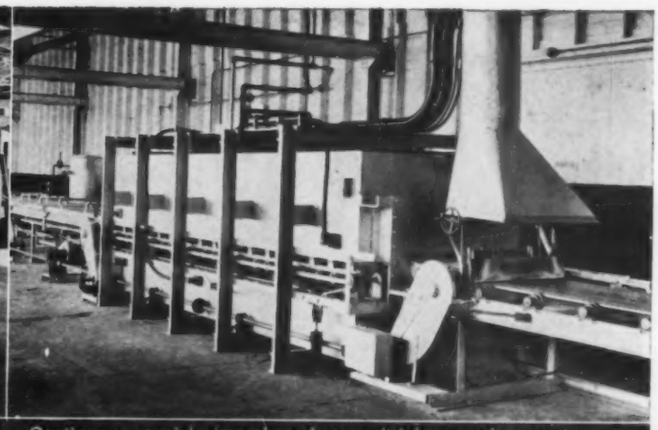
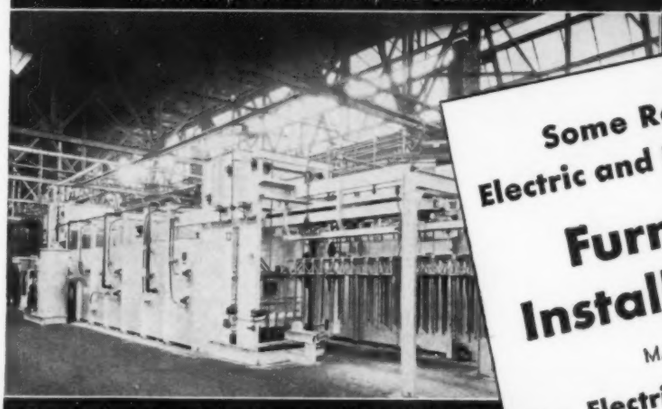


Special atmosphere continuous furnace, bright annealing cold rolled steel in strip form—uniformly and economically.



Continuous, special atmosphere furnace bright annealing steel tubing. Any diameter or length successfully handled in this type furnace.



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**Some Recent Electric and Fuel-Fired**

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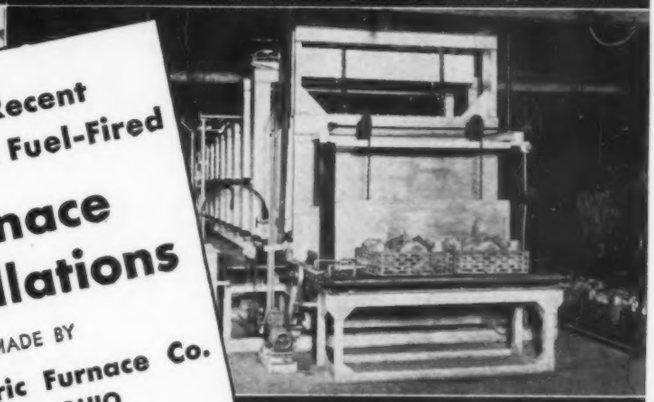
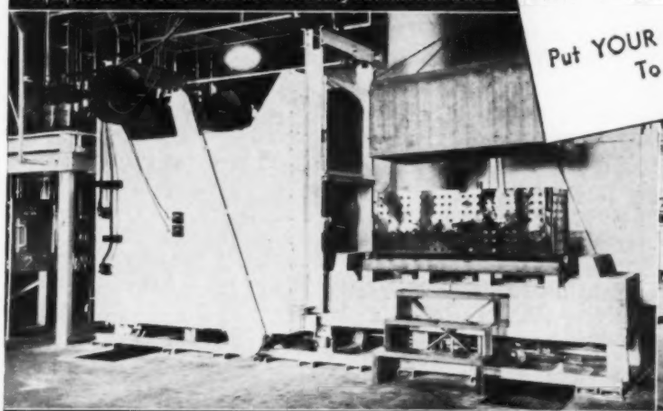
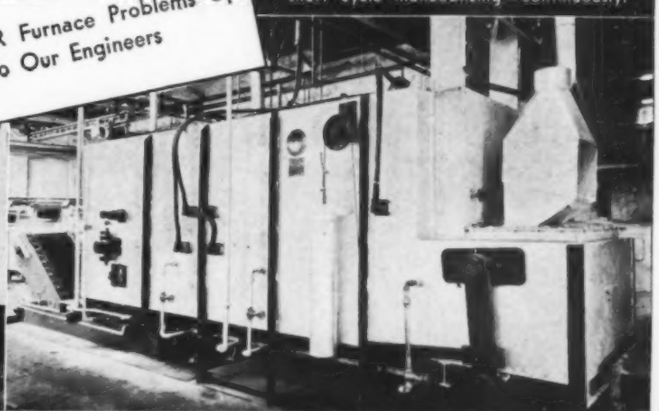
Put YOUR Furnace Problems Up To Our Engineers



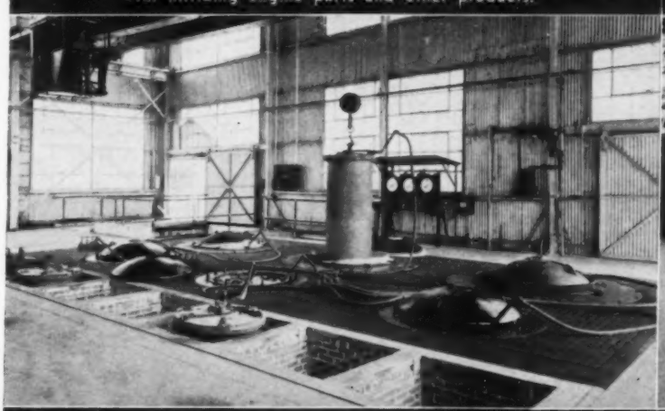
Special atmosphere furnace for scale-free, short cycle malleablizing—continuously.



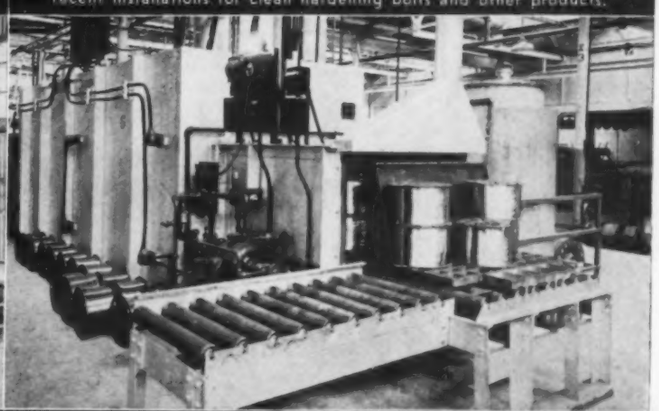
Semi-continuous nitriding furnace—one of several recent installations for nitriding engine parts and other products.



Chain belt conveyor furnace with special atmosphere. One of several recent installations for clean hardening bolts and other products.



Several pit-type installations similar to the above have recently been made for bright annealing wire and normalizing rod.



Special atmosphere furnace bright annealing fine and heavy copper wire on spools, reels and in coils—continuously.

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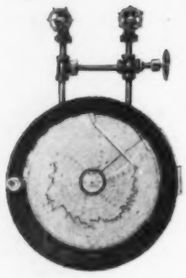
## PER HOUR
## and
# LESS B. T. U.
## PER TON



Mechanical Flow Meter

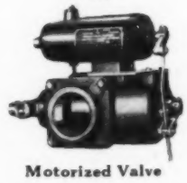
Electric Thermometer

Air-o-Line Potentiometer Controller

Millivoltmeter Pyrometer

Electric Flow Meter

Area Flow Meter Body



Motorized Valve

Indicating Millivoltmeter Controller

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Millivoltmeter Pyrometer

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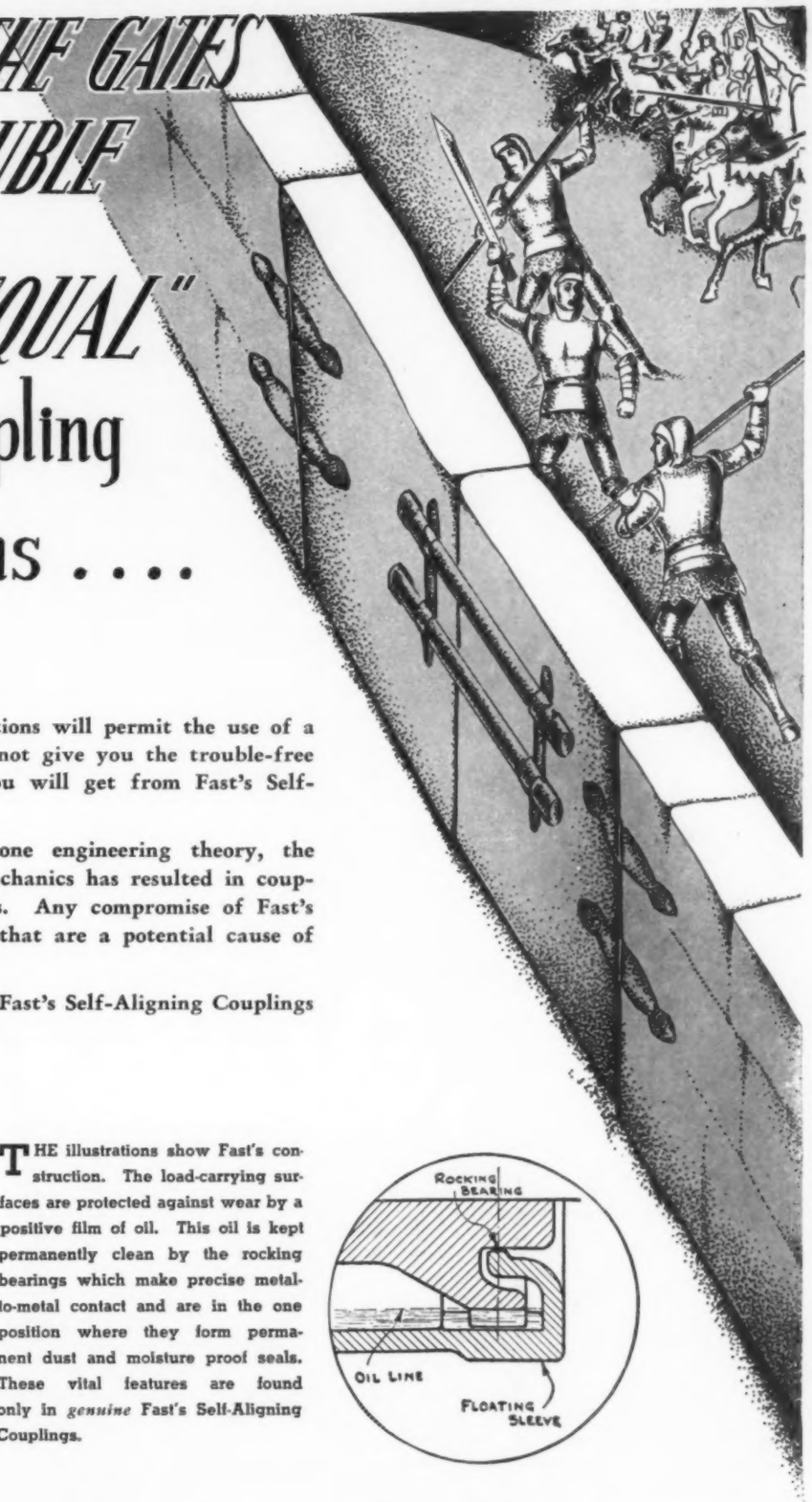
when you write

# "OR EQUAL"

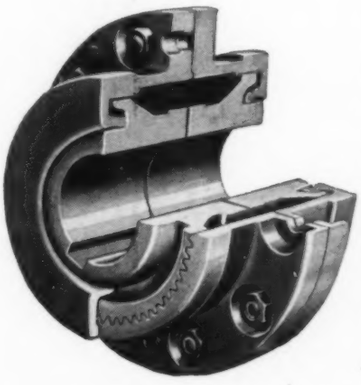
# in your coupling specifications . . . .



AN alternate in your specifications will permit the use of a cheap substitute that will not give you the trouble-free performance that you know you will get from Fast's Self-Aligning Couplings.

Fast's Couplings embody the one engineering theory, the one design, which applied to mechanics has resulted in couplings that are free from defects. Any compromise of Fast's principle introduces weaknesses that are a potential cause of operating troubles.

*Make sure* . . . specify *genuine* Fast's Self-Aligning Couplings on the machinery you purchase.



THE illustrations show Fast's construction. The load-carrying surfaces are protected against wear by a positive film of oil. This oil is kept permanently clean by the rocking bearings which make precise metal-to-metal contact and are in the one position where they form permanent dust and moisture proof seals. These vital features are found only in *genuine* Fast's Self-Aligning Couplings.

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